Do gamma-ray bursts hold secrets of the infant universe? How astronomers are finding out. p. 34

June 2008

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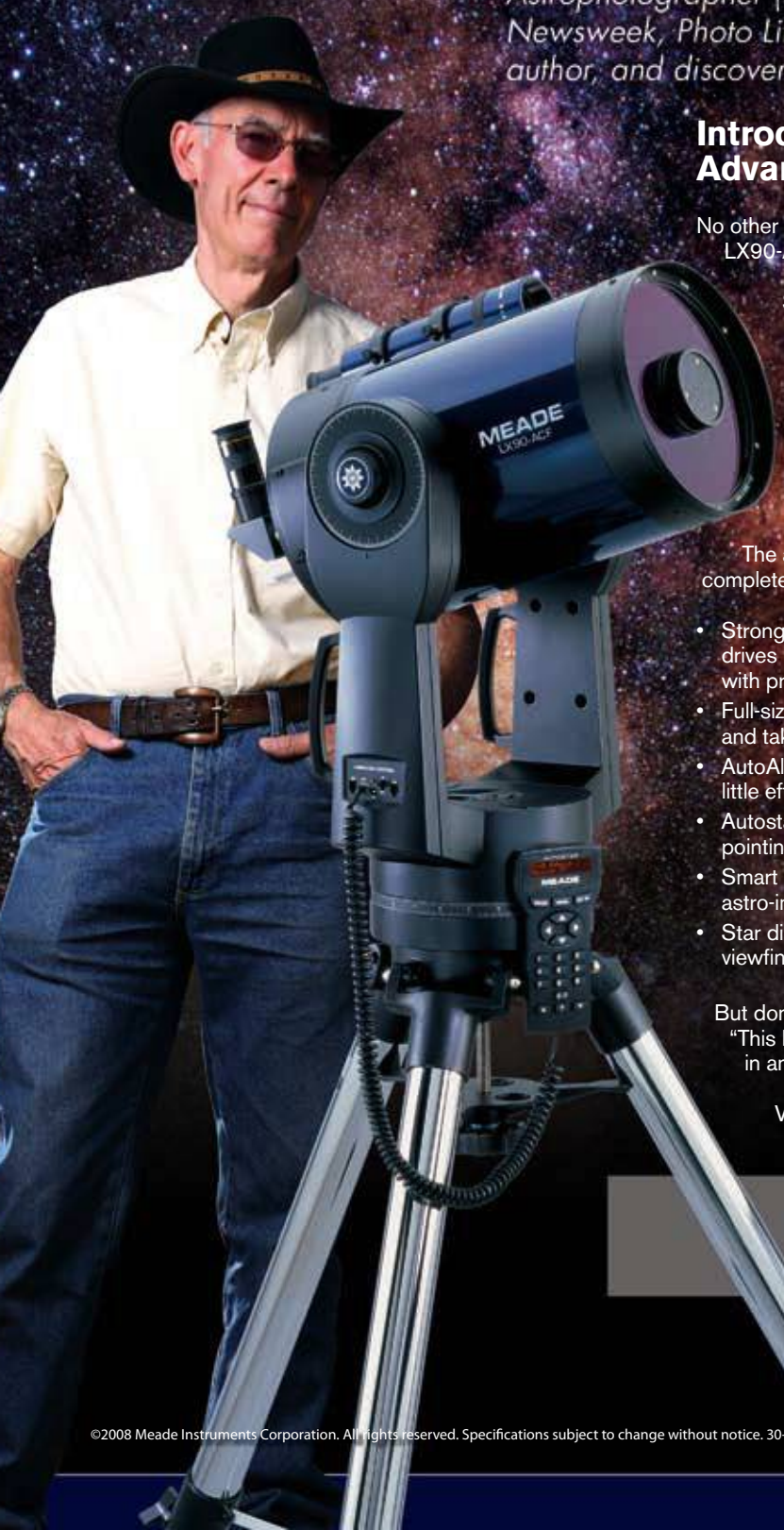

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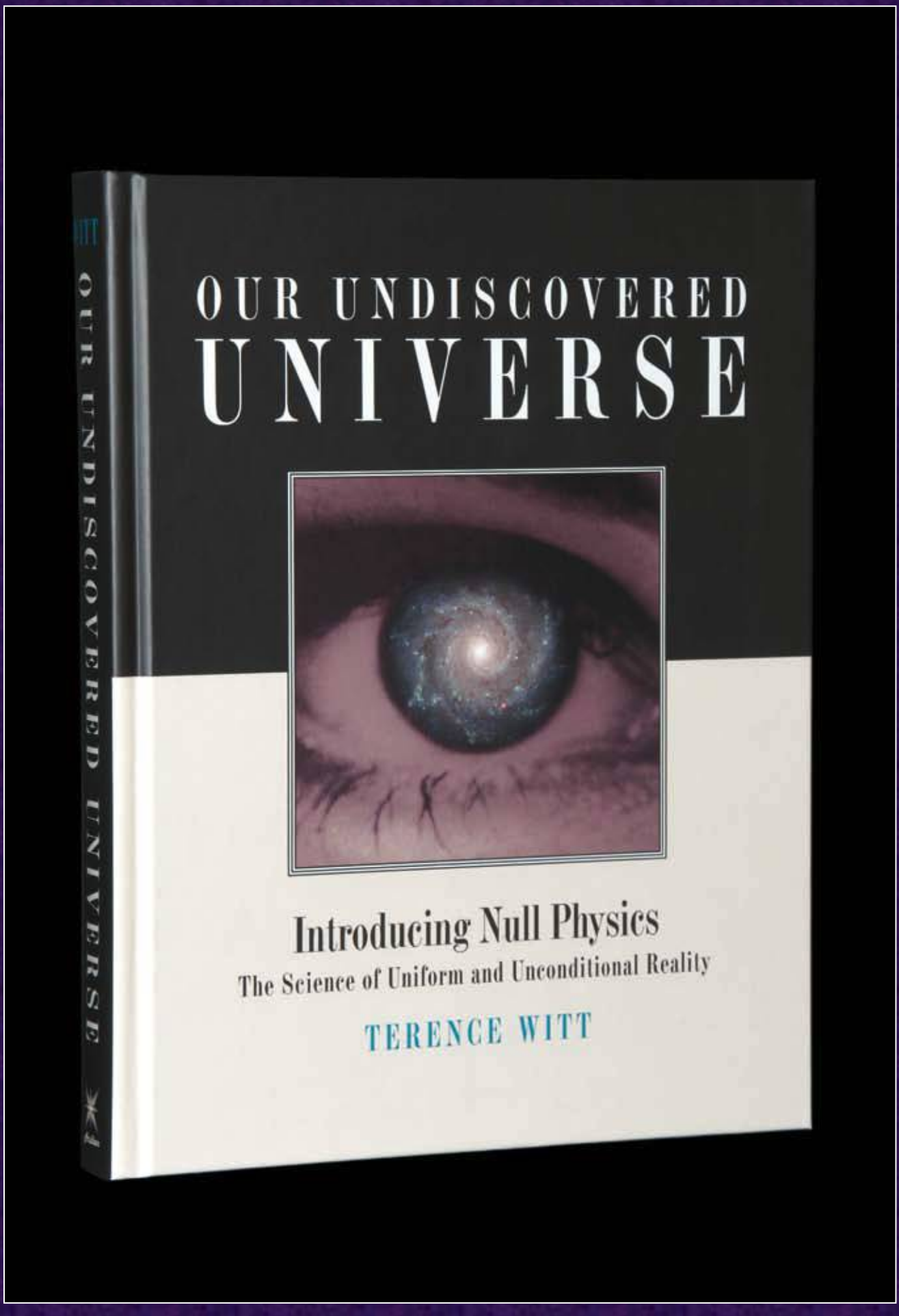
OUR UNDISCOVERED UNIVERSE
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Introducing Null Physics
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TERENCE WITT

Theoretical physics has been hopelessly stalled for over 30 years. Moribund. Ossified. The Standard Model of particle physics uses over 20 ad hoc constants, and no one knows why they are necessary or why they have the values they do. Quantum physics and general relativity remain utterly incompatible. Cosmologists haven't the foggiest idea what could have caused the Big Bang or what, if anything, came before it. And finally, afte over 30 years of effort, string theory hasn't even achieved the status of *science*.

There is a very simple reason for this catastrophic, intractable mess. Theorists stopped asking *why* a long time ago. Without the *why*, the search for mathematical symmetries becomes numerology, not science. No telescope or particle accelerator, regardless of its size, is going to tell us *why* the universe is the way it is. When the *why*'s remain unanswered, there is no understanding. When there is no understanding, there is no progress. But this ad situation is about to change forever.

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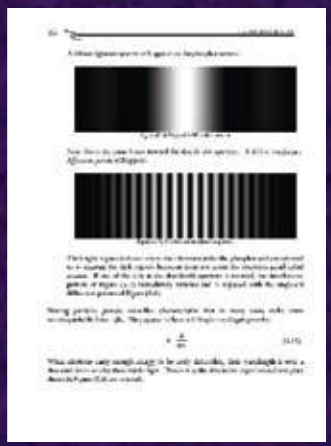
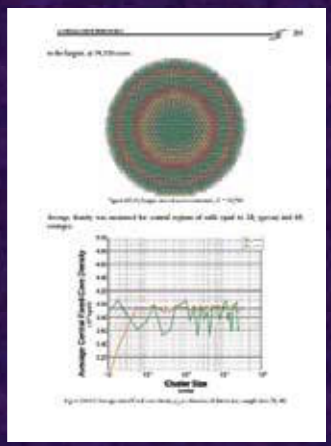
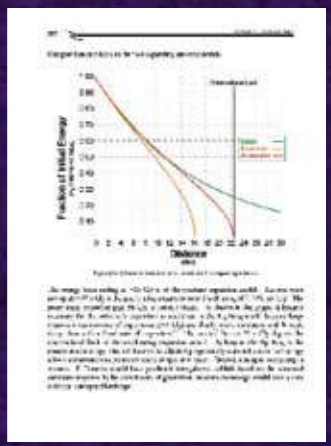

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Astronomy

VOL. 36, NO. 6

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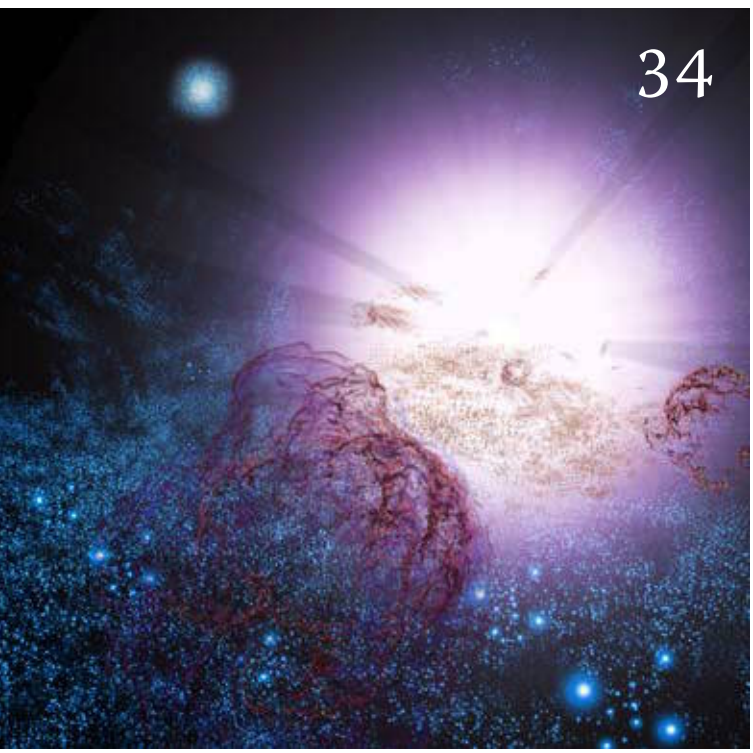

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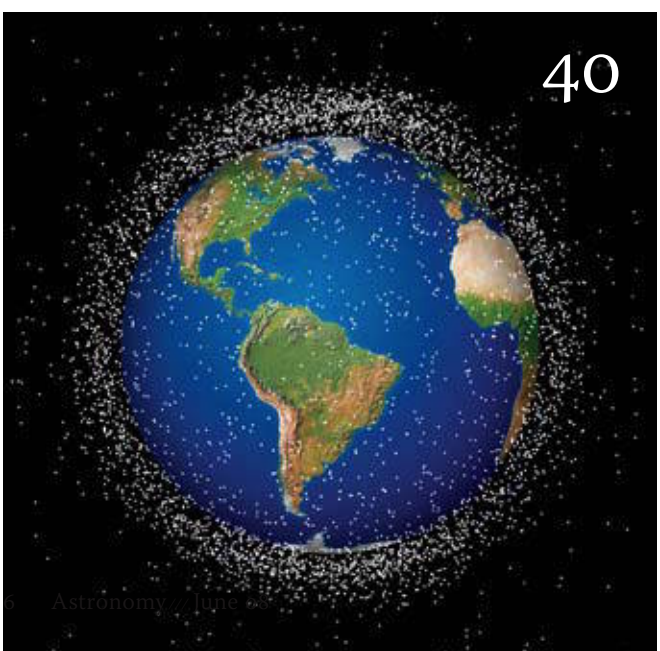

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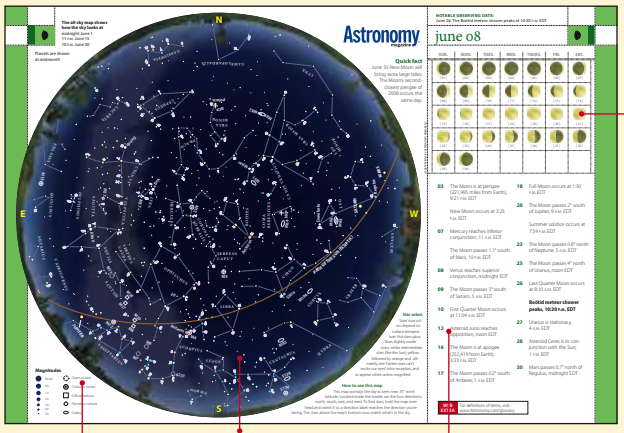

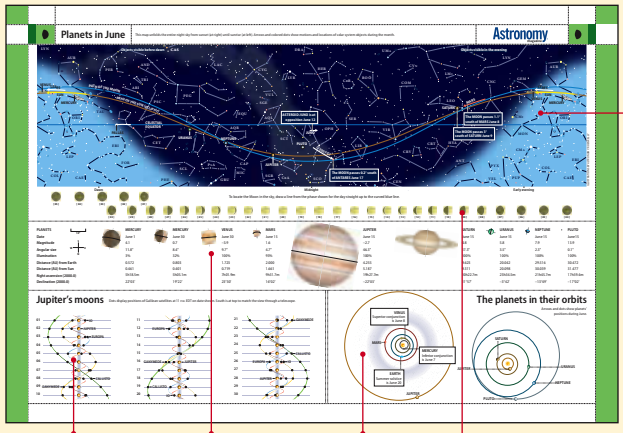

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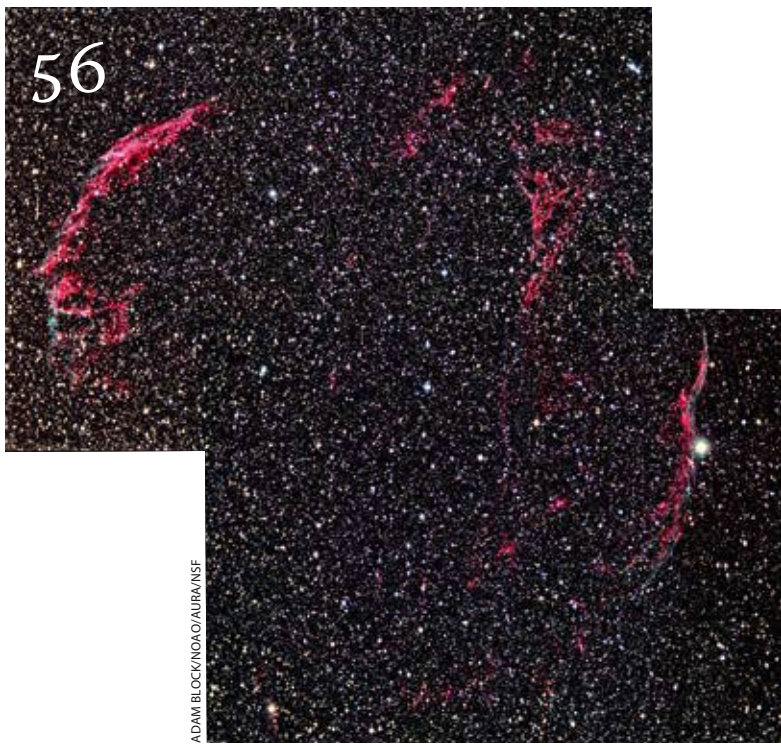

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Introducing *Extreme Weather*

The editors of *Astronomy* have been busy producing a special issue that focuses on a subject we're all fond of: the weather. We've assembled a fantastic package aimed at the science behind weather in many interesting aspects. *Extreme Weather* will be on newsstands everywhere June 17. I'm sure you'll be delighted at what you see.

In *Extreme Weather*, you'll read an account of noted storm chaser Warren Faidley pursuing the Woodward tornado and, the following day, witnessing the effects of a different tornado that virtually obliterated Greensburg, Kansas, May 4, 2007. You'll learn everything about lightning, its beauty and deadly power, from an article by Senior Editor Frank Reddy.

In his story about climate change, Robert Henson of the University Corporation for Atmospheric Research tackles the state of scientific understanding of global warming. He previews what the world will be like in 50 years.

Astronomy's Associate Editor Daniel Pendick contributes two stories. Pendick investigates research suggesting that warmer sea-surface temperatures could spawn more intense, frequent, and long-lined tropical storms. He also looks back to America's deadliest weather tragedy, the Galveston, Texas, hurricane of 1900.

This exciting issue contains a whole lot more. I think you'll be delighted.

I also have some news about the people who bring *Astronomy* to you. Our managing editor, Dick McNally, has been promoted to executive editor. Dick's many years of service in various areas of publishing have helped in leading him to this special position. Congratulations, Dick!

Also, we are thrilled to announce that Associate Editor Laura Baird and her husband Jonathan welcomed twin girls, born March 3. While Laura is away, Kathy Meyer, a veteran of Milwaukee's *Journal Sentinel* will fill in for Laura.

ASTRONOMY: WILLIAM ZUBACK

Executive Editor Dick McNally

Associate Editor Laura Layton has left our staff to pursue a journalism career at NASA's Goddard Space Flight Center.

Finally, please join us in welcoming Jeff Felbab, *Astronomy*'s new advertising sales manager. Jeff has a wealth of experience in magazine, broadcast, and Internet sales and management. He is a graduate of the University of Wisconsin-Whitewater, and he and his family enjoy boating and numerous other outdoor activities. Welcome, Jeff!

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 36, Number 6

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Sailing through Puppis

A distant galaxy seems to cower in fear as the cometary globule CG4 looks ready to devour it. Located in the southern reaches of Puppis the Stern, the two unrelated objects lie at vastly different distances. CG4 resides in our own galaxy, some 1,300 light-years from Earth, while the edge-on spiral ESO 257-19 dwells 135 million light-years away. Cometary globules are isolated star-forming regions that have no relation to comets, except for a vague similarity in shape. This globule's head spans about 1.5 light-years, while its tail stretches 8 light-years. The entire cloud of gas and dust contains enough material to make several Sun-sized stars. T. A. RECTOR (UNIVERSITY OF ALASKA, ANCHORAGE)/T. ABBOTT/NOAO/AURA/NSF

Can we colonize Jupiter's Moons?

In "Earth's deadly future" (July 2007), the sidebar on page 31 by Richard Talcott says that in the far future, humans might someday relocate to Jupiter's moons Europa, Ganymede, and Callisto. However, Jupiter now possesses a powerful and deadly radiation belt encompassing all three moons. The problem with this idea is Jupiter's radiation belts. The Galileo space probe was designed to be highly radiation-resistant. Jupiter's radiation has exactly the same bad effect on living organisms that they do on electronics.

— **DALE A. WOOD,** CULLMAN, ALABAMA

You are right that Jupiter's radiation would be lethal to unprotected humans. But the chance is pretty good we will have solved those problems in 4 to 5 billion years.

— **RICHARD TALCOTT,** SENIOR EDITOR

Slow time

In "Other dimensions" (February 2008), I must take exception to Bob Berman's description of time dimensions. According to Einstein, high velocity makes time pass at a slower pace. Thus we would "see" time moving very slowly on a planet in such a place, not more quickly.

— **CHRIS DASKALAKIS,** YONKERS, NEW YORK

Confusion over whose time passes at what rate is natural, because I failed to specify whose frame of reference we're using. To aliens on that distant high-speed planet, things are as I said in the column: A brief snack-time passes for us while a million years passes for them. I was talking about other dimensions, so I was alluding to a different time experience by beings on another world.

It's actually easy to keep track of relativity's time dilation when it comes to high-speed travel: Your local time seems normal and correct, whereas time always runs slower for the other guy! My point was simply that the universe is truly filled with "time dimensions" in which the passing of time changes with varying circumstances. — **BOB BERMAN,** CONTRIBUTING EDITOR

Correction

In "250 million years ago, did an asteroid nearly end all life on Earth?" (April 2008), biographical data on author Joel Davis was incorrect. He is a writer in Bellevue, Washington, not Sacramento, California, and is not the author of *The UC Davis Sweetheart Murders*. — ***ASTRONOMY* EDITORS**

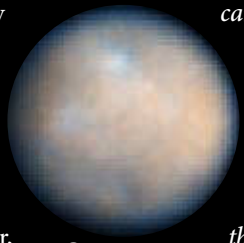
We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

EUROPA, Ganymede, Callisto, and Io lie within Jupiter's radiation belts. Could human settlers survive there anyway? NASA/JPL-CALTCH

Reader cites dwarf-planet double standard

As someone who still feels Pluto got a raw deal, I have to nitpick your double standard. In "Sharpest snapshots ever of Pluto's tiny moons" (February 2008, page 21), you refer to Pluto as a dwarf planet. But in "25 years ago in *Astronomy*" (page 18), you say the Dawn mission is headed to the "minor planet" Ceres.

The same decision that demoted Pluto promoted Ceres to dwarf planet status. So either both should be referred to as dwarf planets, or, if Ceres is still a minor planet, then Pluto is still a planet. — **JOHN A. FERKO,** U.S. AIR FORCE ACADEMY, COLORADO



Ceres NASA/ESA

You are correct — sort of! Astronomical nomenclature, especially with regard to asteroids and comets, is notoriously confusing. A "minor planet" to my way of thinking is a solar system body smaller than major planets, but larger than meteoroids — say, about 33 feet (10 meters) across. (Oh, boy, I can just hear the sound of asteroid and comet researchers sharpening their knives to carve up that definition!) But, in any case, the dwarf planet Ceres (not to mention Eris) certainly fits the generic definition of a minor planet. Think of it this way: All bodies larger than meteoroids orbiting the Sun are minor planets, including Ceres. But Ceres and Pluto enjoy the additional appellation of "dwarf planet."

— **DANIEL PENDICK,** ASSOCIATE EDITOR

BY BOB BERMAN

Another Earth

Of all hobbies and pastimes, astronomy might seem the most relaxed. We're not birders freezing for hours waiting for a grackle. We're not gardeners watching deer munch on our petunias. Our subjects essentially live forever. Once we've seen Sagittarius rise, we know the constellation will do it again at that same horizon spot all the years of our lives.

OK, I made up that "serene" stuff. To encourage newbies, we don't immediately tell them about the universe's temperamental side. We demonstrate astrophotography by first shooting the no-brainer Moon. We pretend constellations make sense by pointing out only the half-dozen that resemble what they're supposed to. "There's Orion. Don't those three stars look like a belt?"

Well, yeah. Or maybe a strip of bacon. The earliest observers actually saw a sheep in that part of the heavens. Honest-to-gosh, a sheep wearing a belt.

Astronomy can be exasperating, as eclipse-seekers discover after they've taken out second mortgages to reach a rat-filled destination like Mumbai, only to find it's overcast. But all that is about to pale. We're being set up for the most frustrating experience in the history of Astroland.

Last fall, for the first time, astronomers analyzed an exoplanet's atmosphere using an ordinary ground-based telescope. This new method works for planets that transit the face of their parent sun. First, we obtain the star's spectrum (composition), then another spectrum when the planet and its surrounding air pass in front, then subtract one from the other. Bingo.

This first success story involves a planet 63 light-years away in Vulpecula, which looks like a fox the same way Justice Samuel Alito resembles Paris Hilton. Astronomers found its atmosphere consists of sodium. Salty air. Weird, but nobody cares since this is a world so brutally close to its star no life could exist anyway. But now that we know the technique works, we'll eventually find a more earthlike planet at a comfortable distance from its star. We'll even find one whose air is delightfully packed with water vapor and oxygen.

Oxygen is huge. No sterile planet should have free oxygen, because that element bonds with just about everything to form oxides, leaving no loose O_2 floating around. The only reason for free oxygen is life, which continually releases it. Here on Earth, oxygen appeared only after life began. We think that will be true everywhere.

> **STAR TRAVEL**
> isn't going to happen in our lifetimes — nor in those of our kids.

Sooner or later, we'll find such a planet, and then we'll suddenly know where life almost certainly exists, which will produce headlines around the world. At the office water cooler, your boss and co-workers, who normally discuss science about as often as your parrot does, will excitedly speculate about the "New Earth."

And then, nothing more will happen. In every other discipline, an amazing discovery leads to a flurry of enterprise. Headline-making breakthroughs in chemistry, genetics, or technology get developed further. Researchers pursue possibilities. Not here.

The public will clamor for NASA to launch a probe or even study the feasibility of a manned trip to investigate Earth II. You and I will simply sigh. We know 60 light-years is relatively next door in a galaxy that stretches 100,000 light-years from end to end. We'll think, "Hmm, today's fastest rockets go 10 miles a second. By mid-century, with maximum financial resources, we might develop one that can move not just twice as fast, but 10 times faster. Fast enough to pass the Moon in a half hour. With such speed, we could reach Earth II in just 112,000 years."

OK, so we don't launch until we can go 1,000 miles a second, maybe by century's end. Such a rocket could take astronauts to the New Earth in 11,000 years. Maybe we'd freeze 'em first, like fudge bars. Our descendents can perform a quick thaw 220 centuries from now, followed by a welcome-back parade. Would the ship's electronics last that long? The warranty would be over. What if their data and videos got erased, and they had nothing to show for the trip? Moreover, language — theirs and ours — would have greatly evolved; we'd be hard-pressed to understand anything they said. Their speeches would be congressional-grade gibberish.

Star travel isn't going to happen in our lifetimes — nor in those of our kids. Once found, New Earth will remain the stuff of dreams and fantasies. We'll point it out at star parties. The mysterious, comfortable place with tantalizing life will be the ultimate cookie jar no amount of reaching can ever grasp.

Expect its discovery during the next decade. For those of us who grew up with an instant-gratification, anything's-possible, let's-go mindset, well, this will probably drive us nuts.

BY STEPHEN JAMES O'MEARA

Readers report

Sharing is a joy doubled. That's why

I want to thank everyone who took the time to tell me about their own observing experiences — those related to wonders covered in this column and to other curiosities in the sky. Now I'd like to share with you a few reader reports.

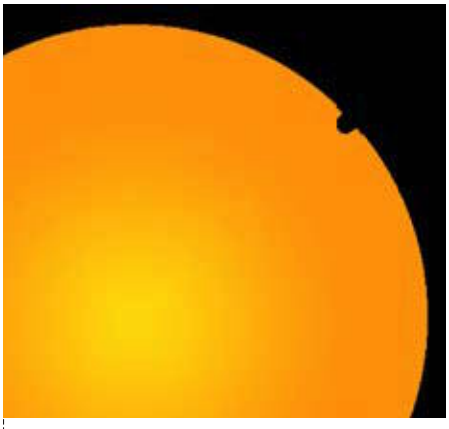
Another mindfreak

In the March 2007 issue, I reviewed some illusions associated with the November 8, 2006, transit of Mercury. After reading that column, Andrew Greenwood, chairman of the Macclesfield Astronomical Society in the United Kingdom, decided to browse through his images and video of the 2004 Venus transit. "While most of what I saw wasn't particularly unexpected (though wonderful to see), there were one or two things that really caught my eye," says Greenwood.

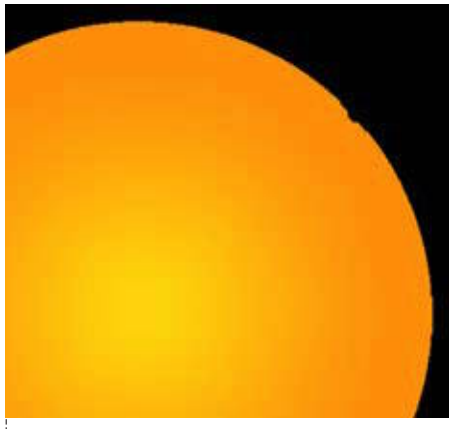
Aside from imaging the beautiful blackdrop effect and some curious aureoles, Greenwood also sketched his view of a dramatic stretching and wide flattening of the planet's silhouette during egress. He also observed a fascinating "pinching in" of Venus' following limb (edge) just before fourth contact. "This effect reminded me of what I've seen many times when the top of the Sun sets and encounters the varying layers of our atmosphere," notes Greenwood. "However, this was happening in inverse — to the bottom of Venus' disk." Anyone interested in sharing their thoughts with Greenwood about his sketches can e-mail him at chairman@maccastro.com.

A crystal arc?

About a week before Frank Manus of the Prescott Astronomy Club in Arizona read my column, "A Crystal Palace," (January 2008), he saw his own puzzling daytime sky phenomenon. "I observed it between 12:30 and 1:30 in the afternoon," he says. "It looked like a circumhorizontal arc with all the colors shown. It was a small segment, and I noticed that it appeared to be part of an inverted rainbow."



THE 2004 VENUS TRANSIT encouraged the observer to sketch the broad flattening of the planet's silhouette during egress. ANDREW GREENWOOD



IN THIS SKETCH, Greenwood observed another illusion he perceived during the transit: the pinching of Venus' limb before fourth contact. ANDREW GREENWOOD

The problem is that the phenomenon did not appear beneath the Sun — in the position of the circumhorizontal arc — but halfway up the northern sky, directly opposite the Sun!

"Our weather had just turned cold," Manus continues, "and there were a lot of moving clouds in the sky, as we have at our altitude of 5,300 feet (1,615 meters). The arc was amid the clouds and that is why it was not too noticeable. It looked like a rainbow but with the arc curving upwards and with the colors reversed. Both my wife and I saw it through our window at the same time."

What was this odd northern light? It could have been a rare, colorful segment of the parhelic circle, which parallels the entire horizon at the same elevation as the Sun. Most parhelic circles look white, because they're created by sunlight reflecting off the vertical faces of horizontally aligned plate crystals. But sometimes they can be enhanced in the part of the sky directly opposite the Sun (the anthelion), and appear as a colorful horizontal band with a bright blue spot. This happens when light passes through hexagonal ice crystals and adds color.

It's also possible Manus saw a rare anthelic arc known as a Wegener arc, which at an altitude of about 45° can bow upward from the parhelic circle at the anthelion and form wide wings of color (red on the bottom and blue on the top). For more information, e-mail Manus at frank.907@msn.com.

Smoking!

In response to my call for interesting Leonid train observations (November 2007), Mike Hutchinson of Muncie, Indiana, wrote to tell me of "the most incredible meteor storm" he's ever witnessed. On November 18, 2001, he and his wife counted 334 meteors between 3:30 and 5 A.M. Using an old Pentax ME 35mm

THE 2001 LEONIDS delivered this smoke ring to the sky above Muncie, Indiana. Shown in this sequence are three images of the stages of the smoke ring captured that morning. MIKE HUTCHINSON

camera on a tripod and Kodak Royal Gold print film (ISO 400), he also recorded several of the brightest meteors and a few colorful, long-lasting, persistent trains. But the show was not over. "At one point, a huge bolide [meteor with a glowing trail] emanated from Leo's head and streaked across the sky," Hutchinson explains. "Then with an audible 'electrical sizzle' it exploded, leaving a distinct, colorful smoke ring."

The smoke ring persisted long enough for Hutchinson to capture images of it. They show the evolution of the ring — actually a hot cylinder of glowing gas — rising as a pair of counter-rotating vortices as upper atmospheric winds act upon it. Over the course of only a minute, Hutchinson notes, the ring drifted and expanded — until it fractured in two. One section expanded vertically and the other flattened out horizontally, directly over Regulus. For more information about Hutchinson's experience and his remarkable photos, e-mail Hutchinson at hutchmeister@comcast.net.

Celestial snow

The November 2007 column also stirred up a fond memory for Jack Estes of Austin, Texas. He got his start in astronomy, he says, by watching the Leonids in 1966. At the time, Estes was a teen living in Abilene — a small, west-Texas town with a population of about 50,000. "That November was hot," Estes recalls, and on the 16th, he went to sleep with the windows open — until he was awakened about 2 in the morning by a "neighbor milkman who was just going to work."

JAMES YOUNG/TABLE MOUNTAIN OBSERVATORY/NASA/JPL

THE 1966 LEONID storm brought an onslaught of meteors that few have witnessed. Eighty-eight meteors appear on the original negative of this 3-minute exposure.

Estes continues the tale: "He yelled so everyone in the neighborhood would wake up and come outside. When we did, we were astounded by what we saw. For 3 hours until a falloff by about 5 A.M., you couldn't point to an area of sky without blocking out several meteors at once. You could sense the motion of Earth through the meteor storm. It was like driving through blowing snow. I've never seen anything before or since in the natural world that was as impressive. The next day, the *Abilene Reporter News* said we had witnessed about 10,000 meteors per hour."

After that spectacle, Estes bought his first telescope, a used Edmund 4¼-inch f/10 reflector, for $40. And though he now owns an 18-inch NightSky Dobsonian and a Celestron Nextstar 11 GPS, no view through them has ever matched his naked-eye view of the Leonids in 1966. You can e-mail Estes at jackestes@hotmail.com.

I'm also interested in learning more about your observations of these and other curious phenomena; send e-mails to someara@interpac.net. And though I cannot publish all responses, just know that I learn from them, nonetheless.

Hot job In March, University of Arizona workers loaded 51,900 pounds (23,590 kg) of glass into a furnace to cast the mirrors for the 8.4-meter Large Synoptic Survey Telescope (LSST).

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews

LOOK OUT BELOW. A tan cloud of martian ice and dust billows upwards after an avalanche on a towering cliff. NASA/UNIVERSITY OF ARIZONA

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Martian probe witnesses avalanches

NASA's Mars Reconnaissance Orbiter (MRO) snapped photos February 19 of martian avalanches as debris fell from a cliff in the planet's north polar region. It was a rare treat for Mars scientists, since spacecraft images of the Red Planet usually capture geologically ancient landscapes frozen in time.

"It really surprised me," says planetary scientist Ingrid Daubar Spitale of the University of Arizona, who first noticed the avalanches in photos taken by the MRO. "It's great to see something so dynamic on Mars. A lot of what we see there hasn't changed for millions of years."

The steep slope, or scarp, towers more than 2,300 feet (700 meters). White carbon-dioxide frost coats the cliff's top, while the pink-brown layers beneath consist of ice, dust, and dark sand-like material in varying mixtures.

Scientists say the avalanches likely began when fine-grained ice, dust, and possibly large blocks of debris detached from the scarp and cascaded down the slope. MRO imaged the fine dust clouds before they could settle out of the atmosphere. The largest cloud is about 590 feet (180m) across. The full image shows at least four.

MRO scientists hope detailed measurements of the avalanche volume, the shape of its source areas, and the slope's grade will help them determine the ice-dust mixture's precise composition. — **FRANCIS REDDY**

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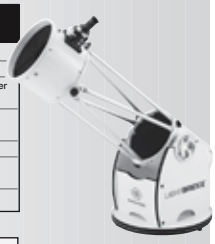

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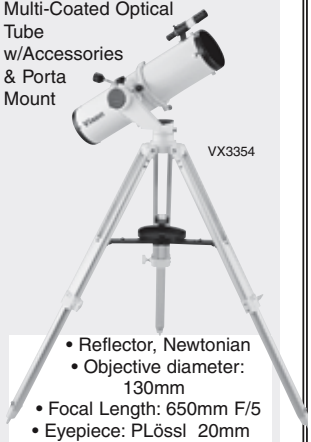

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Earth-forming stars are common in the Milky Way

NASA/JPL-CALTECH/R. HURT (SSC-CALTECH)

ROCKY ROAD. This artist's image depicts the diverse types of rocky, Earth-like worlds that could evolve around stars with dusty disks.

An infrared survey of the Milky Way found 20 to 60 percent of Sun-like stars in our galaxy sport dusty disks that could spawn rocky "terrestrial" planets similar to Earth, scientists reported February 1 in *Astrophysical Journal Letters*. The astronomers used NASA's Spitzer Space Telescope to accomplish the survey.

The team looked at 6 sets of Sun-like stars to determine what our planetary system looked like in its early stages of growth. "We wanted to study the evolution of the gas and dust around stars similar to the Sun and compare the results with what we think the solar system looked like at earlier stages during its evolution," says University of Arizona astronomer Michael Meyer, coauthor of the report.

Spitzer found warm disks encircling 10 to 20 percent of the stars in the four youngest age groups. "That's comparable to the time scales thought to span the formation and dynamical evolution of our own solar system," says Meyer. "Theoretical models and meteoritic data suggest Earth formed over 10 to 50 million years from collisions between smaller bodies." — **MEGAN McCHAIN**

25 years ago in *Astronomy*

June 1983

The distant universe remains undisturbed by human presence because it would take thousands of years to reach even the closest star with the fastest spaceship we could conceivably construct. So how do astronomers measure the distant universe if, practically speaking, we can't get anywhere near it?

In "How far the stars" in the June 1983 issue, Francis Reddy (now a senior editor at *Astronomy*) wrote about the parallax method and other ways to measure distances. Astronomers use parallax for distances within about 300 light-years from Earth. Parallax provides the foundation for understanding star formation and determining the size of far-away objects.

"A nearby object, as seen from opposite ends of a baseline, appears projected on the background in a different place," Reddy wrote. "This can be translated into an angle called the object's parallax."

Once astronomers know the angle and the baseline, simple trigonometry yields the distance.

10 years ago in *Astronomy*

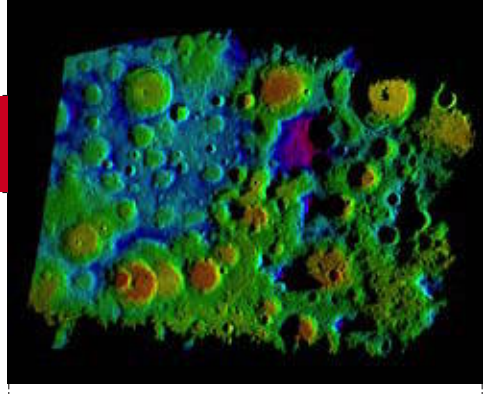
June 1998

In the June 1998 feature, "Jumping Jupiter," *Astronomy* associate editor Richard Talcott — now a senior editor — wrote about the spacecraft that was the first to conduct extended observations of the giant planet Jupiter: Galileo.

Launched in October 1989, the Galileo spacecraft answered many questions about Jupiter and its four largest moons: Europa, Ganymede, Callisto, and Io. The unmanned space probe went to Jupiter to capture close-up views of the four moons and Jupiter itself.

Galileo was the first spacecraft to determine the planet's inner structure. In addition, Galileo captured numerous mind-blowing images of Jupiter and the Galilean moons.

Some Galileo images provided evidence to support a theory that liquid oceans exist under the icy surface of Jupiter's moon Europa. After three extensions, The Galileo spacecraft's mission finally ended in September 2003. — **M. M.**



ROUGH GOING. New maps reveal rugged terrain at the Moon's south pole. On this radar image, purple represents the highest terrain and red the lowest. NASA/JPL

Radar maps Moon's south pole in detail

Recently completed mapping of the Moon's south pole shows it to be a mountain-climber's fantasy, with soaring mountains and plunging valleys. NASA scientists discussed the findings February 28 at the third Space Exploration Conference in Denver.

The region may prove a possible site for future human bases. Permanently shadowed craters could harbor deposits of water ice, while crater rims drenched in perpetual sunshine could generate solar power. But the going could be rough for astronauts on the surface.

NASA scientists have just finished mapping the south pole and found it more extreme than Earth's craggiest terrain. "We now know the south pole has peaks as high as Mount McKinley and crater floors four times deeper than the Grand Canyon," says Doug Cooke of NASA Headquarters in Washington.

Scientists at the NASA Jet Propulsion Laboratory bounced radar off of the Moon's south polar region three times over a 6-month period. Signals that hit an area about 400 by 250 miles (650 by 400 kilometers) across were then picked up at NASA's Goldstone Solar System Radar facility in the Mojave Desert. They revealed house-sized lunar features.

The 1994 Clementine spacecraft resolved features as small as 0.6 mile (1 km) per pixel — the best previous maps. The Goldstone map improved detail by 50 times. As for future human missions, Cooke says, "These data will be an invaluable tool for advanced planning." — **RICHARD TALCOTT**

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NEARBY. **The NEAR/Shoemaker probe is among several spacecraft that experienced unexplained velocity changes.** NASA

Earth flybys reveal mystery speed change

Spacecraft flying past Earth inexplicably gain or lose an iota of velocity as they swoop past our planet, according to a study in the March 7, 2008, *Physical Review Letters*. Vehicles with trajectories past Earth least symmetrical to the equator appear to feel the effect most strongly. The findings suggest scientists' understanding of the forces affecting spacecraft may be lacking.

John D. Anderson at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, led the team that analyzed six flybys by five different spacecraft between 1990 and 2005. Controllers planned each Earth flyby to provide a gravitational tug that would help "slingshot" the probes to destinations elsewhere in the solar system.

On January 23, 1998, the NEAR/Shoemaker spacecraft's speed increased by 0.029 mph (0.047 km/h). At a mere millionth of NEAR's velocity, the change was too small to require a course correction. The real problem is that scientists don't understand the effect's cause.

A decade ago, Anderson identified similar speed shifts for the Pioneer spacecraft, which underwent unexplained decelerations, or "anomalies," as it exited the solar system. Two decades of Pioneer tracking data is available for study. Anderson hopes to analyze it soon.

"I want to concentrate on the Pioneer 11 Saturn flyby first and see if the Pioneer anomaly 'turned on' then," Anderson says. "Some work I did years ago suggests that is the case." — **F. R.**

NASA's new gamma-ray eye in the sky

Astronomers have a new space observatory: GLAST, for Gamma-ray Large Area Space Telescope. Skywatchers on Earth also will be able to keep an eye on the new satellite, which in its low orbit will trace a medium-bright point of light across the night sky much like the Hubble Space Telescope.

GLAST's planned orbit lies at an altitude of about 360 miles (560 km) and at an angle to the equator of about 30°. At half Hubble's size, it will be not quite as bright, but still an easy naked-eye target.

NASA is holding a contest to rename the 1,955-pound (4,300 kg) satellite more imaginatively. Whatever GLAST's official name ends up being, scientists will think of it as the heir to the Compton Gamma Ray Observatory. That satellite, also a favorite naked-eye target for amateur astronomers, spent 10 years mapping gamma-ray bursts (GRBs) and other exotic targets.

Compton was the second of NASA's Great Observatories. Upon its 1991 launch, the 17-ton Compton satellite tipped the scales as the heaviest astrophysics instrument ever flown.

Compton's heir will explore the usual astrophysical targets: blazers, pulsars, stellar flares, GRBs, neutron stars, supernovae, and active galactic nuclei. But GLAST also will target objects within the solar system and seek evidence of the "dark matter" that, hypothetically, comprises most of the universe's mass.

Most exciting, the observatory will keep an eye out for unnoticed or unrecognized phenomena. Large segments of the gamma-ray spectrum remain virtually unexplored, according to program scientists. Compton saw hints of such interesting and unexpected phenomena.

For this reason, GLAST's designers included a special instrument — the Large Area Telescope (LAT) — to take a broad, detailed survey at a wide spectrum of gamma-ray energies. The second main instrument is the GLAST Burst Monitor, which will detect GRBs.

The LAT is called "large area" because it sees one-fifth of the entire sky simultaneously. And it can do so once every 3 hours, detect sources 30 times dimmer than ever seen, and locate them to an accuracy of 1 arcminute. That's equivalent to the optical acuity of a person with 20/20 vision. The LAT also operates over short time intervals, so it will detect targets visible for only a moment, or that dim and brighten quickly.

NASA/KIM SHIFLETT

LAUNCH PREP. **In March, technicians readied GLAST for launch at a processing facility near Kennedy Space Center, Florida.**

GLAST's Gamma Burst Monitor has similar sensitivity, but can't survey more than half of the sky — the half not blocked by Earth — at any given time.

The burst monitor will expand on tasks NASA's SWIFT astrophysical observatory currently performs. SWIFT alerts astronomers to GRBs so they can quickly target them with ground-based instruments. SWIFT also observes the X-ray, ultraviolet, and optical afterglows of GRBs.

GLAST's broad coverage of the gamma ray spectrum will provide the first measurements of the total energy released by events such as GRBs. The new satellite will give scientists access to the most energetic phenomena in the cosmos. And it also will collect more data about these processes at the sub-atomic level.

GLAST's targeted questions read like an astrophysicist's lifetime wish list: How do black holes accelerate jets of material to nearly light speed? What triggers gamma-ray bursts? And beyond the "known unknowns," GLAST will search for "unknown unknowns." What else out there is gleaming with gamma rays that we haven't even noticed yet? — **JAMES OBERG**

LARGE BINOCULAR CAMERA TEAM (ROME UNIVERSITY)

DOUBLE VISION. This new image of NGC 2770 combines ultraviolet and green light to emphasize clumpy regions in the galaxy.

Binocular Telescope snaps first image

And the lucky galaxy is … NGC 2770, a spiral star city some 102 light-years away and the subject of the first image snapped by the Large Binocular Telescope's twin 8.4-meter primary mirrors. NGC 2770 has a flat disk of stars and glowing gas and is tipped slightly toward our line of sight. Science teams in the United States, Italy, and Germany released the image March 6.

The LBT is the world's most powerful telescope. It has a light-collecting area equivalent to a single 39-foot (11.8m) mirror. Special instruments that combine light from each of the LBT's identical mirrors produce image sharpness equivalent to that of a single 75-foot-wide (22.8m) telescope mirror. The observatory sits in the clear air atop 10,480-foot (3,195m) Mount Graham in southeastern Arizona.

"The LBT gives me the most satisfaction of any astronomy project I've worked on, because it is very revolutionary, and because it has given Arizona the largest and the best telescope in the world," says University of Arizona astronomer Roger Angel. In the early 1980s, Angel and other UA astronomers dreamed up the LBT's binocular design. — **DANIEL PENDICK**

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ORGANIC. HD 189733b, illustrated here, has an atmosphere that contains methane — the first organic molecule detected in an extrasolar planet. NASA/ESA/G. BACON (STScI)

Hubble identifies exoplanet's methane

On March 20, astronomers using the Hubble Space Telescope announced that the atmosphere of a gas-giant planet orbiting a star 63 light-years away contains methane. The finding marks the first detection of an organic molecule in the atmosphere of a planet orbiting another star.

Methane is important because it's thought to play a role in chemical reactions that could support life. "This is a crucial stepping stone to eventually characterizing prebiotic molecules on planets where life could exist," says Mark Swain of NASA's Jet Propulsion Laboratory in Pasadena, California. Swain led the discovery team, which reported its findings in the March 20 issue of *Nature*.

The planet, called HD 189733b, is a Jupiter-like gas giant thought to be too massive and hot to host life. The alien world lies so close to its parent star that it completes an orbit in just over 2 days.

When the planet passed in front of its sun in May 2007, Hubble captured starlight that passed through the planet's atmosphere. Gases in the atmosphere imprinted onto the light their unique spectral "fingerprints," which Hubble detected.

The study also confirmed the presence of water molecules in HD 189733b's atmosphere, a discovery made last year by NASA's Spitzer Space Telescope. — **F. R.**

KEEP WORKING. The Spirit rover took this self-portrait last October. The rover's solar panels are so coated with dust that they almost blend into the background. NASA/JPL/CORNELL

NASA budget woes spare Spirit rover

On March 25, NASA rescinded a $4 million cut to the Mars Exploration Rover program that would have meant placing the Spirit rover in hibernation and scaling back activities for its twin counterpart, Opportunity. The U.S. space agency said the directive had not been cleared through NASA Administrator Michael Griffin.

NASA needs to tighten its belt to offset cost overruns associated with its Mars Science Laboratory (MSL). MSL is a bigger, more powerful rover NASA hopes to land on the Red Planet in 2010. Unanticipated costs include the redesign of MSL's heat shield after the original version failed tests. The project is about $100 million over budget.

In a statement, Griffin said that no Mars rover operations would "be suspended or shut down. This means that the Mars Exploration Program will not take any action as a result of the initial letter" indicating reductions in the budget.

The twin rovers, located on opposite sides of Mars, entered their fifth year of operation in January. Their primary mission ended after 3 months. — **F. R.**

Titan may sport a subsurface sea

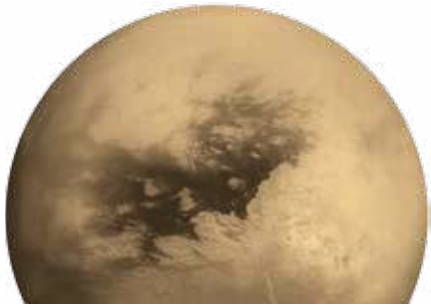
Radar data from the Cassini spacecraft suggest Titan, Saturn's biggest moon, holds an underground ocean of water and ammonia. Scientists believe the ocean lies some 60 miles (100 kilometers) beneath the moon's surface.

A team led by Ralph Lorenz at the Johns Hopkins Applied Physics Laboratory in Laurel, Maryland, reported the findings in the March 21 issue of *Science*. The evidence comes from radar studies of the way Titan spins.

Cassini's radar imaged the moon's surface during 19 separate passes between October 2005 and May 2007. Using data from the radar's early observations, the scientists and radar engineers established the locations of 50 unique surface landmarks.

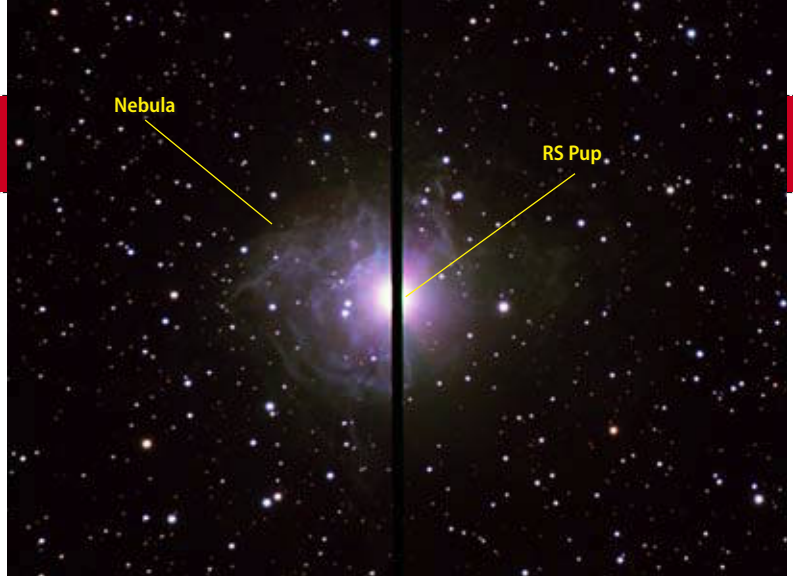
But when scientists searched for the same features in data from later Cassini flybys, they found the landmarks had moved by up to 19 miles (30 km). An ocean layer between the moon's icy crust and its core would give Titan's surface the mobility it needed to explain the spacecraft observations.

"Further study of Titan's rotation will let us understand the watery interior better," Lorenz says. "And because the spin of the crust and the winds in the atmosphere are linked, we might see seasonal variation in the spin in the next few years." — **F. R.**



ESA/NASA/UNIV. OF ARIZONA

CRUST AHOY. Cassini scientists say Titan's icy surface floats on a water-ammonia sea.



STELLAR YARDSTICK. The Cepheid variable star RS Pup helped astronomers develop a better way to measure stellar distances. The middle gap marks the space between two light detectors in the instrument used to produce this color image. ESO

NTT refines distance to key yardstick stars

American and European astronomers used the 3.6-meter New Technology Telescope at La Silla Observatory in Chile to make the most accurate measurement to date of a Cepheid variable star's distance. The team's findings were accepted for publication in *Astronomy and Astrophysics*.

Cepheids enable astronomers to measure vast distances across space and time, frequently to study the origin of the universe. The international team studied RS Pup, a bright Cepheid located in the constellation Puppis.

Cepheids are a type of variable star, meaning they dim and then brighten in a regular pattern. How quickly the star's brightness varies reflects how much light the star actually produces, or its "inherent" brightness. By determining the Cepheid's true brightness, astronomers can, in turn, use it as a "standard candle" to gauge the distance to a remote galaxy: The dimmer the Cepheid, the farther away it — and its host galaxy — lies.

RS Pup is the only Cepheid known to be embedded in a gas cloud, or nebula. Light rays from RS Pup bounce off blobs of gas in the nebula and arrive at Earth slightly later than light streaming directly from the star. The delay is known as a light echo.

By measuring multiple light echoes from different places in the nebula, the astronomers determined RS Pup is 6,500 light years from Earth, plus or minus 90 light years. **— D. P.**

Space-bound robot dives under icy Wisconsin lake

Scientists tested a saucer-shaped submarine February 13, 2008, that may someday explore the subsurface oceans of Jupiter's moon Europa. The craft sank beneath the icy surface of Lake Mendota in Madison, Wisconsin, on its first-ever "sea trials." The test dives were the probe's first in cold water.

Christened ENDURANCE — for Environmentally Non-Disturbing Under-ice Robotic ANtarctiC Explorer — the vehicle swims untethered under ice. Its instruments create three-dimensional maps of the underwater environment and characterize water chemistry and biology.

Not accidentally, *Endurance* was the name of the ill-fated ship that British explorer Sir Ernest Shackleton sailed to Antarctica in 1914. Ice crushed the ship, the crew abandoned it, and many barely escaped with their lives after much suffering.

The shepherds of the new ENDURANCE hope to have better luck. The team's next expedition will be to Antarctica's permanently frozen Lake Bonney. The 130-foot-deep (40m) lake lies within the continent's McMurdo Dry Valleys. It is perpetually trapped beneath up to 15 feet (4.6m) of ice. ENDURANCE will map Bonney for a month, then perform a second mapping in 2009.

The University of Illinois at Chicago, Montana State University, NASA's Ames Research Center, and Texas-based Stone Aerospace are collaborating on the $2.3 million project. **— F. R.**

JEFF MILLER/UW-MADISON

FRIGID DIVE. A crane lowers the robotic submersible Endurance into Madison, Wisconsin's Lake Mendota for a frigid test drive.

QUICK TAKES

GOOD SHOW!
At 7 P.M. EST February 4, NASA's Deep Space Network beamed the Beatles song "Across the Universe" into space to commemorate the agency's founding in 1958.

DATA GUSHER
In March, NASA released 5 years of data collected by the WMAP satellite. Astronomers say the data fine-tunes the universe's age.

COSMIC TRIAD
The Arecibo Radio Telescope discovered that asteroid 2001 SN_{263} comprises three bodies orbiting each other. The largest is 1.5 miles (2 km) wide.

NEW MISSION
In January, the Deep Impact spacecraft began looking for new planets transiting five stars already known to harbor at least one "hot Jupiter."

GOING TO THE ISS
The Canadian Space Agency announced February 11 that Julie Payette and Robert Thirsk will rocket to the International Space Station in 2009.

STORM LAUNCH
Scientists announced in January that thunderstorms can launch high-energy electron beams into space.

BIG BLOCKS
NASA's Mars Reconnaissance Orbiter imaged debris blocks up to 164 feet (50m) across. The blocks formed when a meteorite struck the planet.

BIG BUDGET
NASA unveiled its $17.6 billion 2009 budget request February 4. It includes a major new mission to explore moons at Saturn or Jupiter.

EARTH NEXT DOOR?
A new computer simulation suggests an Earth-like planet orbits Alpha Centauri B. The system is the nearest to us, just 4.37 light-years away.

LUNAR RADIO SCOPE
NASA selected an MIT plan to design a radio telescope for the Moon's far side. The scope would probe the period before the first stars ignited.

Ox watch

University of Washington scientists plan to use satellite data to warn native people in the Arctic of impending die-offs in herds of musk oxen and other hoofed animals.

Giant stars may have little helpers

NASA/ESA/N. SMITH (UNIV. OF CALIFORNIA, BERKELEY) ET AL./HUBBLE HERITAGE TEAM (STSCI/AURA)

THAT'S A BIG ONE! Large stars like Eta Carinae contain more than 100 times the Sun's mass. They may owe their existence to an earlier generation of small "helper" stars.

Massive stars form in giant interstellar gas clouds largely because of nearby, smaller "helper stars" about the size of the Sun. The helper stars create an environment in which giant-star growth is possible, astronomers proposed February 28 in *Nature*. Containing up to 150 times the mass of the Sun, giant stars are relatively rare in our galaxy.

Astrophysicist Christopher McKee, of the University of California in Berkeley, and Mark Krumholz, an astronomer at the University of California in Santa Cruz, created a computer model of giant star birth in large clouds of cool gas. Normally, such clouds "fragment" into smaller clouds and give birth to many small stars comparable to the Sun in mass.

McKee and Krumholz propose that giant stars form if, early in the process, a handful of smaller helper stars start to coalesce. This heats the gas enough to keep it from breaking into fragments. This allows a large star to form by drawing in much of the available gas.

"What it comes down to is that if a cloud is too cold, it tends to break up into many small pieces that become low-mass stars," Krumholz explains. "As the cloud gets warmer, though, it can make bigger and bigger objects."

For conditions to be ripe for giant-star formation, helper stars have to expand a cloud to a density of about 1 million hydrogen molecules per cubic centimeter. In distant galaxies with clouds that don't meet this threshold, giant-star formation may be low.

Because giant stars are so bright and easily visible through telescopes, astronomers count them to indirectly estimate star-formation rates in distant, dim galaxies. Their absence would prevent astronomers from accurately estimating star-formation rates in some galaxies, McKee and Krumholz say. **— M. M.**

Studies reveal stony asteroid surprise

Contrary to scientists' assumptions, the meteorite that slammed into Carancas, Peru, September 15, 2007, was moving at tremendous velocity. And this explains why the object, even though composed of stone, made it to the surface and gouged out an impressive pit instead of breaking into fragments higher up.

Two independent teams presented their findings about the event March 11 at the 39th Lunar and Planetary Science Conference in Houston. Peter Schultz of Brown University headed one team. Thomas Kenkmann of the Museum für Naturkunde, Mineralogie at Humboldt-Universität in Berlin led the other group.

Around noon September 15, residents in the town of Carancas saw a bright fireball streaking overhead. Eyewitnesses reported the fireball had a luminous head and a white tail. The resulting explosion smashed windows up to 0.6 mile (1 kilometer) away and created a crater 49 feet (15 meters) across. The impact gouged out some 4,500 cubic feet (130 cubic meters) of a dry stream bed and flung it up to 330 yards (300m).

Nothing seemed odd about all this — until scientists examined the scene in detail. "This just isn't what we expected," says Schultz. "It was to the point that many thought this was fake." The surprise arose when the researchers realized the impacting body was a stony meteorite, a fragile type scientists thought would get ripped to pieces as it tore through Earth's atmosphere. Obviously, that didn't happen.

The atmosphere typically slows such a meteorite down, and it leaves a small pit — not a crater — when it hits the ground. "But this meteorite kept on going at a speed 40 to 50 times faster than it should have been going," or about 15,000 mph (24,000 km/h), says Schultz.

Schultz thinks the disintegrating meteorite's fragments simply couldn't escape the surrounding shock wave. Instead, they coalesced into a more aerodynamic shape. Like a football spiraling through the air, the incoming meteorite easily penetrated the atmosphere and remained intact all the way down to the surface.

If Schultz is right, scientists should be able to find other small craters created by stony-meteorite impacts. Unfortunately, erosion and weathering will render them unrecognizable as extraterrestrial features within a short period.

Already, the Peru crater is losing features that make it an obvious impact site. "You just wonder how many other lakes and ponds were created by stony meteorites," says Schultz. **—R. T.**

HOLY METEORITE, BATMAN! The 49-foot-wide (15m) Carancas crater in Peru surprised scientists because it formed from the impact of a fragile stony meteorite. PETER SCHULTZ

SHINE ON. Astronomers mapped this dense gas filament by measuring scattered light from background stars. ESO

New technique peers into dark space clouds

Astronomers using the 3.6-meter New Technology Telescope (NTT) in La Silla, Chile, have found a way to probe dark gas clouds otherwise impenetrable to telescopic investigation, according to a study published March in *Astronomy and Astrophysics*. The new technique allows study of dark clouds with higher accuracy and greater depth. This can assist in understanding the process of star-formation in such clouds.

The NTT targeted the Corona Australis molecular cloud, a cigar-shaped, 45 light-year-long body of gas and dust about 500 light-years away. The scientists focused on one feature: a dense filament of gas that blocks most light.

The study employed an instrument sensitive to near-infrared wavelengths. When light from stars behind the filament enters the cloud, gas scatters it. Astronomers have dubbed this scattering effect "cloudshine."

The denser the gas in a certain portion of the cloud, the more light it scatters. The more scattering that occurs, the redder the background stars appear. Astronomers can use the reddening effect to map variations in gas density within the cloud. Observing in the near-infrared means the NTT can map clouds at greater depth than visible-light instruments. — **D. P.**

Space station robot helpmate goes to work

Dextre, a two-armed space robot and helpmate to the crew of the International Space Station (ISS), blasted off March 11 aboard the space shuttle Endeavour. Shuttle astronauts managed to get Dextre working despite a faulty power circuit on the robot.

Developed by a private contractor for the Canadian Space Agency, Dextre is the final component of the Mobile Servicing System, Canada's contribution to the International Space Station. Dextre's arrival marked the debut of the completed system on the ISS (see "Space Science Update," January 2008).

The ISS crew took delivery of Dextre in nine modular components. Astronauts performed three space walks to assemble the robot to its full height of 12 feet (3.7m). Dextre can move along a rail system or ride the end of ISS' Canadian manipulator arm, Canadarm2.

ERECTOR SET. Space shuttle astronauts assemble the Dextre robot. NASA

The robot's mobility and flexible joints will allow it to perform maintenance and repair tasks that would otherwise require dangerous space walks by ISS crew members. — **D. P.**

BRIEFCASE

Dogging Apophis

In February, U.S.-based SpaceWorks Engineering won $50,000 in a contest sponsored by The Planetary Society, a space advocacy group, to design a spacecraft mission to shadow and study the near-Earth asteroid, Apophis 99942. — D. P.

Google me to the Moon

To win the $30 million Google Lunar X PRIZE, you merely need to land a robot rover on the Moon and rove around a bit. In December 2007, the British firm Odyssey Moon announced it would vie for the private-exploration prize. — D. P.

NASA's lunar sandbox

If you enjoyed playing in the sandbox, you'll love NASA's Regolith Excavation Challenge. For prizes totalling $750,000, competitors must build a machine to dig into a sandbox of simulated lunar soil (regolith). The machine must operate fully independently. — D. P.

Runaway star is not from our neighborhood

Astronomers have determined the origins of a star flung at enormous velocity from its home galaxy — and it isn't our Milky Way, as earlier suspected. In a report published March 10 in *The Astrophysical Journal*, a team of scientists asserts the runaway star came from the Large Magellanic Cloud (LMC), a satellite galaxy of the far larger Milky Way 160,000 light-years from Earth.

The star, HD 0437–5439, is speeding away from the Milky Way at 1.6 million miles per hour (2.6 million km/h). The star's relatively young age, 35 million years, suggested it has traveled too far to come from our home galaxy. But which one, then?

Astronomers from the Carnegie Institution of Washington (CIW) and Queen's University in Belfast, Ireland, believe they've solved the puzzle. A previous study lacked details of HD 0437–5439's elemental composition. The latest data on the star's metal content points to an LMC origin.

"We've ruled out that the star came from the Milky Way," explains Alceste Bonanos of the CIW. "The concentration of elements in the Large Magellanic Cloud stars are about half those in our Sun."

Although we know where the star once called home, another puzzle remains. The star's speed of rotation indicates it was part of a binary system. The location of the star's partner remains unclear.

One theory is that a black hole, at least 1,000 times the mass of the Sun, swallowed the other star. As the black hole claimed this star, HD 0437–5439 was whipped out of the LMC. No evidence exists of this black hole, however. — **JEREMY McGOVERN**

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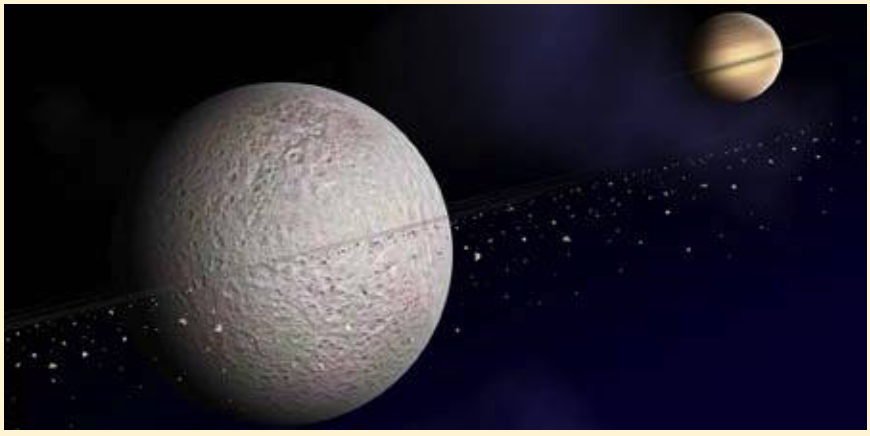


CHUNKY. Saturn's moon Rhea may have a dusty debris disk and embedded rings of boulder-sized material, as seen in this artist's rendering. JPL

Ringed planet may have ringed moon

Rhea, Saturn's second-largest moon, likely sports a debris disk and at least one ring, scientists with NASA's Cassini mission reported March 7 in *Science*. If confirmed, it represents the first discovery of rings around any moon in the solar system.

"Until now, only planets were known to have rings, but now Rhea seems to have some family ties to its ringed parent Saturn," said study leader Geraint Jones at London's Mullard Space Science Laboratory.

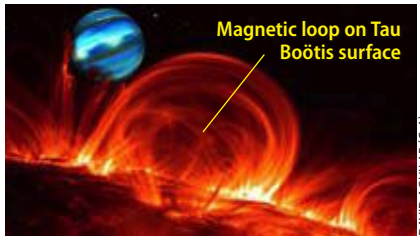
During Cassini's November 26, 2005, flyby, the spacecraft passed 310 miles (500 kilometers) from the icy moon, which is 950 miles (1,500 km) across. Cassini's instruments found large regions on either side of Rhea with lower-than-expected numbers of energetic electrons. Cassini scientists believe the best explanation for the electron blackout is the presence of dust and ice, which block the electrons from reaching the spacecraft's detectors. — **F. R.**

Astronomers witness alien star flip-out

Telescopes in France and Hawaii observed, for the first time, another star's magnetic field reverse polarity, an international team of astronomers reported February 25, 2008, in the online version of the *Monthly Notices of the Royal Astronomical Society*.

A gaseous "hot Jupiter" planet orbits Tau Boötis every 3 days. The exoplanet is about 1,400 times more massive than Earth, scientists estimate.

Astronomers Jean-Francois Donati (Observatoire Midi-Pyrénées) and Claire Moutou (L'Observatoire Astronomique Marseille Provence) led the effort. The project harnesses an astronomical power couple: the Canada-France-Hawaii Telescope atop Mauna Kea and the Bernard Lyot Telescope on a mountain in the French Pyrenees, Pic du Midi. In 2006, the France-Hawaii team made the first measurements of Tau Boötis' magnetic field, which is about 100 times weaker than a typical refrigerator magnet.



DAVID AGUILAR (CfA)

FLIP OUT. Tau Boötis' magnetic field flips direction every several years. This artist's view shows the star's giant planet.

The Sun's magnetic reversals occur every 11 or so years (a new cycle began in January). They mark the ebb of sunspots and other solar activity. Tau Boötis spins about 9 times faster than the Sun. This means Tau Boötis could undergo a full cycle in just a few years. — **F. R.**

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5 billion years A.D.

Our galaxy's date with destruction

The Milky Way is on a collision course with its neighbor, the Andromeda Galaxy. What will the night sky look like after the crash? /// BY ABRAHAM LOEB AND T.J. COX

Our galaxy, the Milky Way, and its nearest large neighbor, the Andromeda Galaxy (M31), are on a collision course. Billions of years from now, the merger will transform the structure of both galaxies and create a new arrangement of stars we have dubbed Milkomeda ("milk-AHM-mee-da"). The merger will radically transform the night sky. But into what?

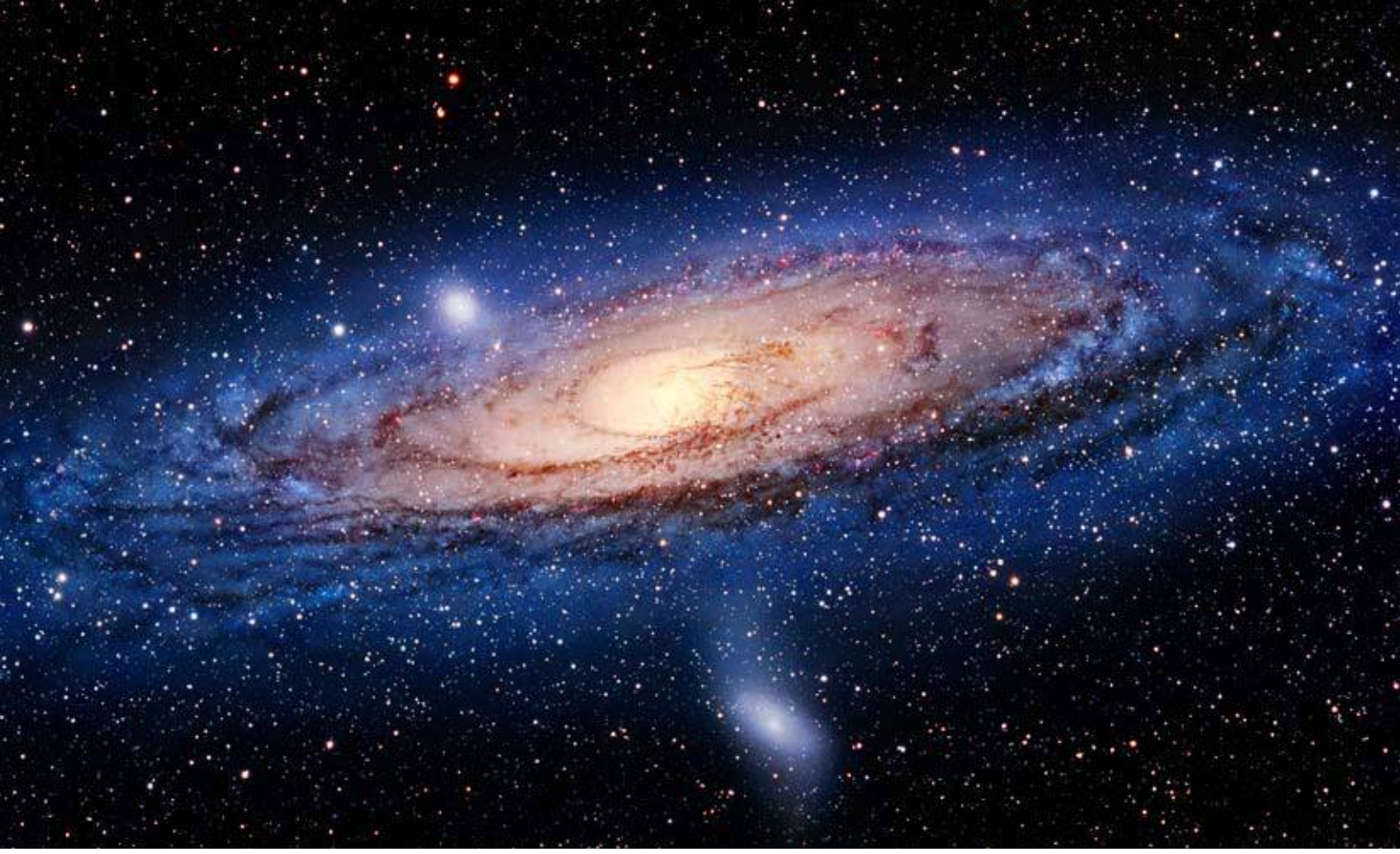
Currently, the Milky Way's thin disk of stars and gas appears as a nebulous strip arching across the sky. As Andromeda grazes the Milky Way, a second strip of stars will join the one that presently graces the night sky in summer. After the final merger, the stars will no longer be confined to two narrow lanes, but instead scatter across the entire sky.

In our research, we have explored the Milky Way's fate by simulating Milkomeda's birth in a supercomputer. The simulations are at a sufficient level of detail (resolution) to learn a lot about the coming merger and how it will change our perspective on the universe. Although we won't be here to witness the event — nor to take responsibility for whether our forecast proves accurate — this is the first research in our careers that has a chance of being cited 5 billion years from now.

The Local Group

The night sky's vastness might suggest the Milky Way resides in a relatively remote part of the universe. However, astronomers know the Milky Way to be the second-largest in the Local Group of galaxies, compared to Andromeda, which is the largest member. It contains somewhat more mass than the Milky Way, lies nearly 2.5 million light-years away,

BILLIONS OF YEARS FROM NOW, the night sky will glow with stars, dust, and gas from two galaxies: the Milky Way, in which we live, and the encroaching Andromeda Galaxy (M31). LYNETTE COOK FOR *ASTRONOMY*



THE ANDROMEDA GALAXY (M31) is a typical spiral of stars, dust, and gas. Spiral galaxies dominate the night sky in the local universe. Fourteen satellite galaxies accompany Andromeda, including the two visible in this image: M32 (above Andromeda) and NGC 205 (below). Andromeda is the largest in the Local Group of galaxies. TONY AND DAPHNE HALLAS

and is visible in the northern sky with the naked eye. The remaining members of the Local Group — several dozen — are a bevy of much smaller satellite galaxies.

A galaxy group comprises two or more relatively close, massive galaxies. The compactness of galaxies that form groups suggests that they are gravitationally bound and dynamically coupled to each other. This simply means the galaxies attract each other gravitationally, so a change in one affects the fate of the other.

Evidence of the dynamic connection between the Milky Way and Andromeda comes from their relative motions. The galaxies are barreling toward each other at nearly 270,000 mph (190,000 kilometers per hour). We know this because the spectral lines of Andromeda's light appear to be blueshifted — displaced toward the blue end of the spectrum — by the Doppler effect. In contrast, most galaxies in the universe are flying away from the Milky Way.

Timing is everything

Nearly 50 years ago, Franz Kahn and Lodewijk Woltjer pioneered the "timing argument." This hypothesis held that the Milky Way and Andromeda formed close to each other, during the dense, early stages of the universe.

Subsequently, the general expansion of the universe pulled the two galactic neighbors apart. Later, the Milky Way and Andromeda reversed their outward trajectories owing to mutual gravitational attraction. Since then, they have completed nearly a full orbit around each other.

The timing argument, combined with estimates of the galaxies' relative velocities and other factors, indicates the Local Group's total mass is about 3 trillion times the Sun's mass. It also suggests the Milky Way and Andromeda will make a close pass in about 4 billion years.

Kahn and Woltjer inspired a generation of studies that further constrained the mass of the Local Group and revealed important characteristics of Andromeda's orbit, such as its total energy of motion.

But the timing argument does not have the ability to follow the complex dynamics that accompany the merger of extended galaxies. Therefore, it cannot predict the future arrangement of the Local Group. For processes as complex as galaxy mergers, astronomers need more powerful tools.

Simulating the Local Group

Numerical simulations are indispensable for understanding processes too complex to solve with pen and paper. In galactic mergers, for example, simple gravity shapes the merged galaxy. But the sheer number of atoms interacting over time makes it difficult or impossible to simulate the merger without massive computer power.

To simulate the evolution of the Local Group, first we create a mathematical model describing its present state. This is straightforward for the Milky Way and Andromeda. Several decades of observations enable us to

Abraham Loeb *is a professor of astronomy at Harvard University, a visiting professor at the Weizmann Institute of Science, and the director of the Institute for Theory and Computation at the Harvard-Smithsonian Center for Astrophysics.* **T. J. Cox** *is a postdoctoral fellow at the Institute for Theory and Computation at the Harvard-Smithsonian Center for Astrophysics.*

estimate the quantity gas, stars, and other matter involved. We can determine a plausible mass estimate for the Milky Way and Andromeda to well beyond the visible inner portion of each galaxy.

However, the combined mass of the Milky Way and Andromeda is still less than nearly every number the timing argument yields. This implies there is additional mass in the Local Group.

The missing mass turns out to be the diffuse "intergalactic medium" of atoms, gas, and dust between the galaxies. Galaxies are simply the visible peaks of massive icebergs of matter. Much of the mass is not readily apparent, just as most of an iceberg's bulk lies underneath the water's surface.

FROM EARTH, we see the Milky Way from an insider's perspective. Depending on the time of year, an Earth-bound observer can see 3 or 4 different arms of the spiral. JOHN CHUMACK

When galaxies collide

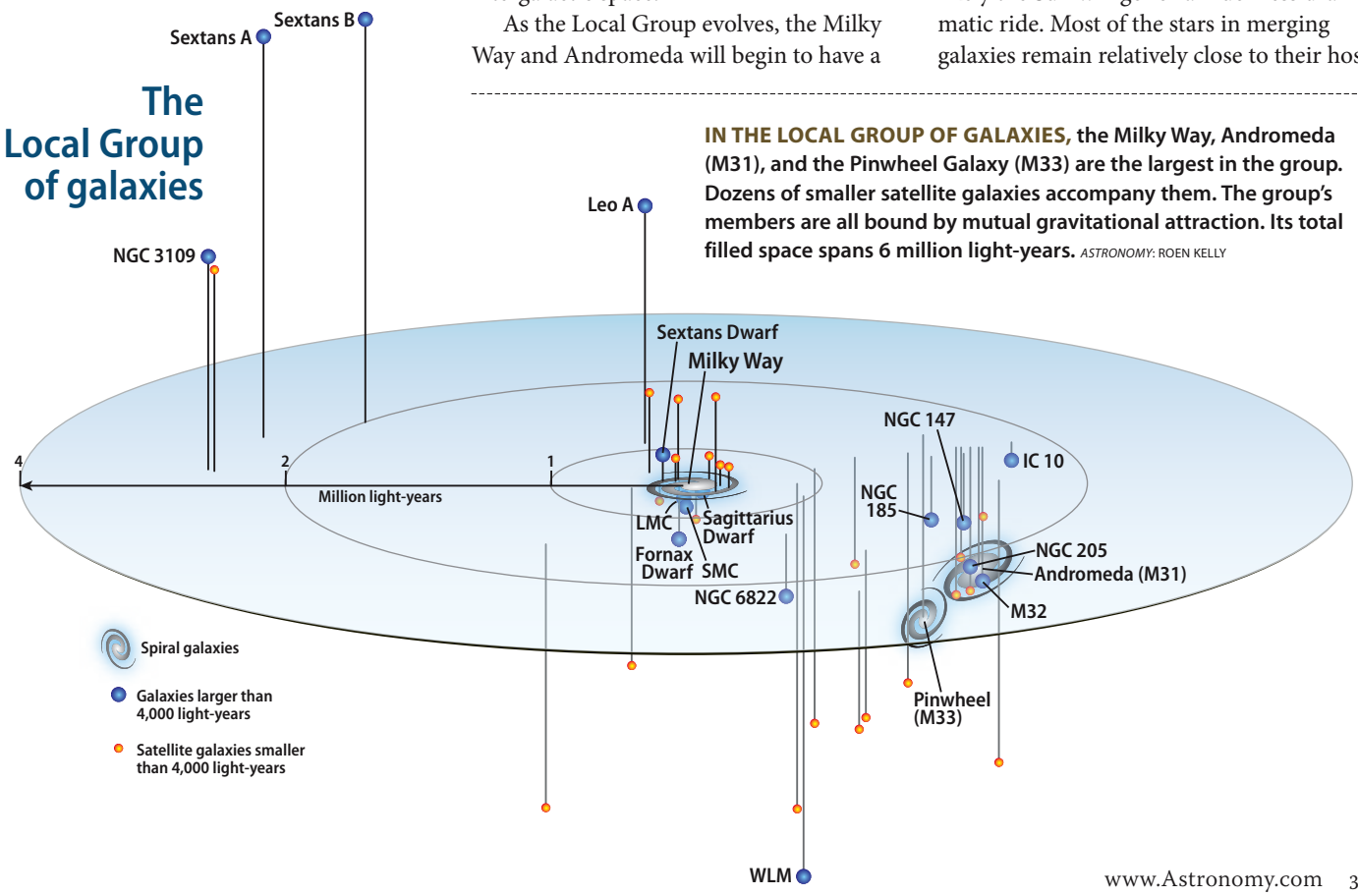
Full-scale simulations typically require 2 weeks of number crunching. This task requires the power of the equivalent of 16 fully loaded desktop computers.

Since the early days of astronomy, merging galaxies have remained curiosities owing to their complex and irregular shapes. But astronomers now appreciate that mergers significantly drive galaxy evolution. Galaxy mergers touch off bursts of star formation, give birth to bright galactic nucleii (quasars), and transform pinwheel-shaped spiral galaxies into smooth spheroidal or elliptical galaxies.

One of the distinguishing characteristics of galaxy interactions is the appearance of long streams of stars and gas that stretch from one or both of the participant galaxies. We commonly call these features tidal tails. They result from the powerful gravitational forces at work between merging galaxies. As the tails form, they rip stars and gas from the host galaxy and hurl it into intergalactic space.

As the Local Group evolves, the Milky Way and Andromeda will begin to have a dynamic impact upon each other owing to their mutual gravitation. As a result, it's possible the Sun — and Earth and the other planets — will be dragged into a tidal tail. During this period, an observer would have one of the most unique vantage points imaginable. Torn shreds of the Milky Way will fill a large fraction of the night sky as our galaxy experiences its gravitational dance with Andromeda.

Because only a small fraction of a galaxy's mass ends up in tidal tails, it is more likely the Sun will go for a much less dramatic ride. Most of the stars in merging galaxies remain relatively close to their host

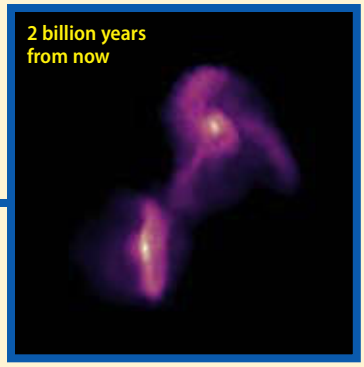


IN THE LOCAL GROUP OF GALAXIES, the Milky Way, Andromeda (M31), and the Pinwheel Galaxy (M33) are the largest in the group. Dozens of smaller satellite galaxies accompany them. The group's members are all bound by mutual gravitational attraction. Its total filled space spans 6 million light-years. *ASTRONOMY:* ROEN KELLY

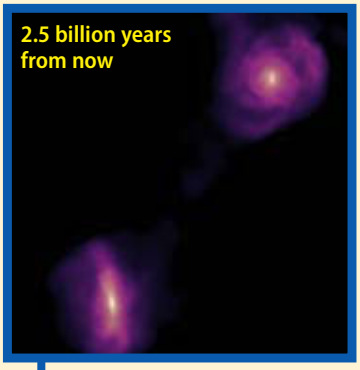
GALAXY MERGERS IN CYBERSPACE

Astronomers don't simulate galaxy mergers just to create pretty pictures. The simulations are serious and time-consuming scientific experiments. Simulations enable astronomers to test new ideas about the merger process and the role of mergers in the evolution of galaxies and the universe.

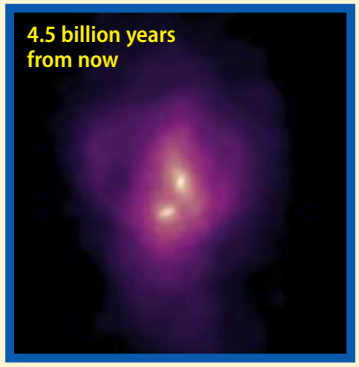
The images below, sampled from a merger simulation by Harvard astronomers T. J. Cox and Avi Loeb, depict the merger of the Milky Way and Andromeda galaxies. These frames highlight important milestones and events in the merger process. UNLESS OTHERWISE NOTED, MERGER IMAGES BY T.J. COX (CfA)



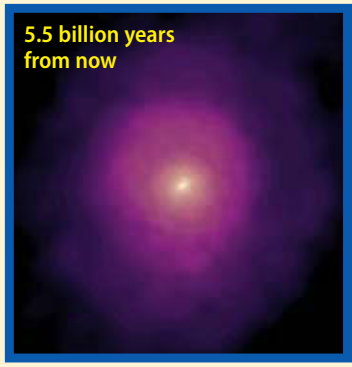
2 BILLION YEARS from the present, the galaxies swing around each other in a close pass. Mutual attraction draws tenuous tidal tails of stars and gas. Tidal tails are hallmarks of mergers in the real universe (see image below).



IN 2.5 BILLION YEARS, the galaxies are still moving apart. A ghostly bridge of gas and stars still connects them. Stars in the bridge, perhaps some with planets, could end up literally lost in space as the galaxy bridge dissipates.



IN 4.5 BILLION YEARS, the galaxies loop around another time and then finally coalesce into a single mass. Their dense cores, each harboring a black hole, gradually combine into a single nucleus. The merging galaxies experience a brief pulse of star formation as the black holes merge.



IN 5.5 BILLION YEARS, Milkomeda is born. Tidal swirls, tails, and eddies left over from the violent merger slowly relax and dissipate. Individual stars spread out, forming a more homogenous elliptical galaxy similar to M32 (right), a satellite of today's Andromeda Galaxy.

NGC 2207 (lower galaxy) as it merges with smaller IC 2163.
NASA/ESA/HUBBLE HERITAGE TEAM (STScI)

JOHN DUBINSKI (WWW.GALAXYDYNAMICS.ORG)

THE BEAUTY of merging galaxies stands out in this simulation of another possible model of the Milky Way-Andromeda collision by astronomer John Dubinski. The simulation reveals more detailed structure than Cox and Loeb's images because it includes more than 300 million particles of interacting matter.

galaxies. The chance of the Sun being banished to the tidal-tail boondocks is relatively small, based on our simulations.

Change of fortune

The Sun's peaceful orbit around the center of the Milky Way — which it has traversed nearly 20 times since its birth — will forever change. Its new path will be far more chaotic owing to the rapid fluctuations in gravity induced by the merger. What would this mean for Earth and its residents?

Our research suggests the Milky Way and Andromeda will begin to interact strongly 2 billion years from now, and then complete the merger in about 5 billion years. The latter date is especially notable because it coincides with the Sun's remaining life span. Currently, our Sun is about halfway through its lifetime and eventually will begin to expand. As it does so, it will consume all its available hydrogen and evolve toward a red-giant phase within 5 billion years. In short, the Sun will be in its death throes on Milkomeda's birthday.

The Sun's red-giant stage will make life on Earth rather uncomfortable. Indeed, it

THE MERGER OF SPIRALS often produces a single, new sphere-shaped type of galaxy called an elliptical. The elliptical galaxy above, M32, is one of the 14 known satellite galaxies of Andromeda. Most galaxies in the Local Group are small satellites. WOLFGANG PROMPER

will spell the end of life as we know it. However, it does not preclude the possibility for colonization of habitable planets around nearby stars. Thus, it is possible future astronomers will be able to witness some, if not all, of the Local Group evolution we have simulated.

Although the Milky Way and Andromeda will merge, stars within the two galaxies, such as our Sun, will not physically collide. The reason is the extremely large distances between individual stars in galaxies. For example, if the Sun were the size of a ping-pong ball, the nearest star (Proxima Centauri) would be another ping-pong ball nearly 1,000 miles (1,600 km) away.

Our final resting place

The Sun's orbit will follow a chaotic path until the merger concludes. At that point, the system will relax and expand. And the Sun will reside inside a new galaxy: Milkomeda. It will look very different from either the Milky Way or Andromeda.

The Milky Way and Andromeda are spiral galaxies, with most stars concentrated into a disk and moving in nearly circular orbits around the galactic center. In contrast, Milkomeda will be nearly spherical in shape and much smoother in appearance than any spiral galaxy. Stars within Milkomeda will follow more complex orbits. The stars will spend brief periods near the dense galactic center, but orbit much farther away most of the time.

Milkomeda's spheroidal shape is not unusual, as it characterizes a major class of objects called elliptical galaxies. Such galaxies typically host relatively old stars. Presumably, many of these galaxies in the present-day universe formed by mergers between galactic disks, in which the stars had formed at earlier cosmic times.

The Sun's likely fate will be to spend much of its time in the galactic outskirts. The merger will redistribute the orbital momentum (energy) of the Milky Way and Andromeda among individual stars in Milkomeda. The stars will end up with more momentum after the merger, and thus will encircle Milkomeda's center at a larger average distance.

The Local Group's far future fate

Because of the universe's accelerating expansion, Milkomeda will not merely be our final resting place. A hundred billion years later, Milkomeda also will represent our entire visible universe.

In the next tens of billions of years, the accelerating expansion of space itself will pull all distant galaxies farther and farther away from us. Once the recession rate of any distant galaxy exceeds the speed of light relative to us, its light will be unable to traverse the inflating gap.

At that point, we will no longer be able to see those galaxies. They will gradually wink out of reach of the most powerful telescopes. No longer will astronomers be able to gaze into the sky and study distant galaxies in order to learn about our own.

However, the prelude to this final gloomy fate would be full of fun. Over the next 5 billion years, astronomers will witness the stellar fireworks in one of the greatest shows of all time: the transformation of the Milky Way and the Andromeda Galaxy into Milkomeda. So sit back and wait for the show to begin.

WEB EXTRA Watch animation of the Milky Way and Andromeda galaxies merging at www.Astronomy.com/toc.

Do cosmic flashes of the

Gamma-ray bursts can outshine 100 million galaxies. Astronomers now think these energetic events offer a window into the distant past. /// BY STEVE NADIS

It's night. You're adrift at sea with no idea where you are. Then, along the horizon, you see a momentary flash — a beacon from a distant lighthouse. For a few seconds, a patch of sky brightens before fading, once again, into darkness.

If you have the right equipment onboard, it can help you determine how far away the lighthouse is. Perhaps it will tell you how foggy the air is between you and the light source. If other lighthouses flash, you might gain some sense of where you are in relation to the land. And, in time, as you witness more and more flashes, you may begin to sketch out the vague contours of the shoreline.

Astronomers would like to do the same thing with distant gamma-ray bursts (GRBs), which they consider one of the best ways to probe the early universe. GRBs are the universe's most luminous events since the Big Bang. In particular, researchers hope to study the first stars and the galaxies they inhabit, to see how the ionization and chemical composition of the gas in and between galaxies changed over time.

"Even with the upcoming James Webb Space Telescope (JWST) at our disposal, we couldn't make measurements like this without the backlights provided by GRBs because there's simply not enough light shining through," explains Harvard astronomer Jonathan Grindlay. Detecting a burst at a redshift of, say, 10, "would be like having this bright spotlight shining on you," says Grindlay. A redshift equal to 10 corresponds to a time less than 500 million years after the Big Bang.

Bursting the gamma-ray bubble

GRBs are the obvious choice for providing background illumination because when they occur they outshine everything in the universe.

GRBs come in two categories. Short-duration bursts, which many scientists believe are the product of two colliding neutron stars, last a fraction of a second. Such events don't interest cosmologists because they lie nearby, occurring when the universe was already about 10 billion years old. Long-duration bursts, which may last tens of seconds, typically lie at much greater distances, flaring when the universe was less than a few billion years old.

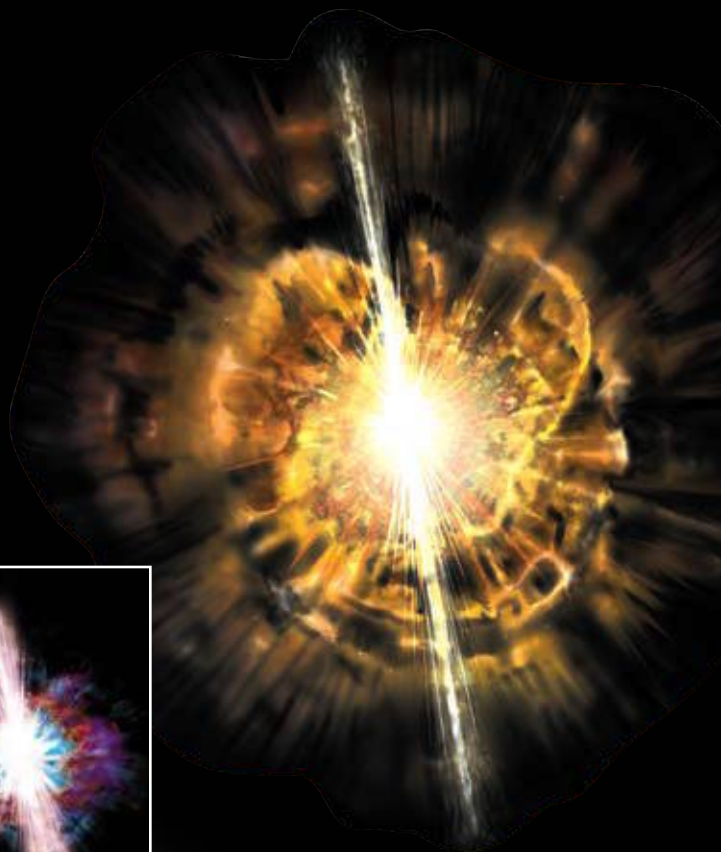
A long-duration burst signals the death of a massive star that becomes either a rapidly spinning black hole (also called a collapsar) or an intensely magnetized neutron star called a magnetar. During the intense burst phase, which may last tens of seconds, GRBs can be 100 million times brighter than an entire galaxy. Powerful gamma-ray jets pour out of the exploding star, heating the gas around it. This creates an "afterglow" in optical to radio wavelengths that remains bright for days.

Astronomers already have charted the universe out to redshift 6 or so (less than a billion years after

► **A LONG-DURATION GAMMA-RAY BURST** forms as a massive star explodes as a supernova. For a brief instant less than a billion years after the Big Bang, it outshines the young galaxy that contains it. DON DIXON

reveal secrets infant universe?

Long-duration gamma-ray bursts



1) A massive star quickly uses its core nuclear fuel. It begins to expand to form a red supergiant.

2) As the star dies, jets of particles we may perceive as gamma-ray bursts stream from the core.

3) Finally, the star explodes as a supernova. The associated long-duration gamma-ray bursts last between 2 and 20 seconds.

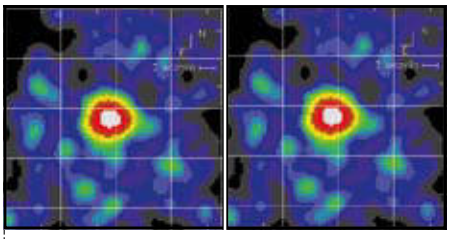
Short-duration gamma-ray bursts

1) Two neutron stars circle each other in a close gravitational dance.

2) Eventually, the stars' gravity pulls them closer, and they spiral toward each other.

3) Their dance ends in an explosive collision — a gamma-ray burst lasting milliseconds and detectable billions of light-years away.

ASTRONOMY: KELLIE JAEGER



ENRICO COSTA/BEPPOSAX TEAM

EIGHT HOURS after astronomers observed a GRB February 28, 1997, the satellite BeppoSAX detected the first X-ray afterglow (left) in the same location, and again 3 days later (right). Afterglows help pin down GRB distances and host galaxies.

the Big Bang) by using quasars. But at significantly higher redshifts, scientists expect to stop seeing quasars long before they run out of GRBs. That's why the more distant, high-redshift bursts interest them: GRBs can chart the universe much farther out.

Old bursts are good bursts

On theoretical grounds, GRBs should exist at earlier times than quasars because of their different origins. Most astronomers believe structure formation is hierarchical: Small assemblages of matter called minihalos formed before larger systems. Astronomers now are searching in small galaxies for GRBs. The minihalos of about 1 million solar-masses that give rise to these galaxies should be fairly common by the time the universe is about 200 million years old, according to University of Texas astrophysicist Volker Bromm.

Quasars, on the other hand, derive their energy from supermassive black holes found in the middle of the largest galaxies that form, in turn, from trillion-solar-mass halos. Giant halos like this become prevalent hundreds of millions of years later.

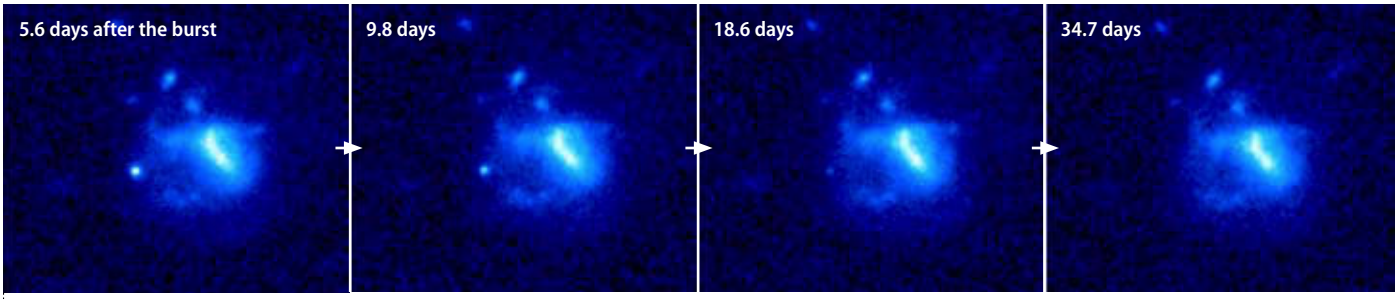
Every high-redshift burst, according to Bromm, "offers a glimpse into the period of cosmic history just after the Dark Ages (a time before the universe was transparent) ended. This is a new frontier in cosmology, affording the chance to explore an epoch about which we know little or nothing."

Astronomers still can't reliably predict the greatest distance at which they'll find a GRB. The Wilkinson Microwave Anisotropy Probe indicated the universe's hydrogen ionized (was stripped of electrons) by the Big Bang's heat. The gas then became neutral again after the universe cooled and started reionizing by the time the universe was 300 to 400 million years old. If stars contributed to the reionization, they must have been present at least that early.

"The most exciting possibility would be if the first generation of stars gives rise to GRBs," notes Harvard astronomer Avi Loeb. "While we couldn't see such a star during its normal lifetime, if we're lucky, we might catch it at the moment of its death."

Stan Woosley, a theorist at the University of California, Santa Cruz (UCSC), believes massive stars have been around for as long as there have been stars. The first stars, composed of only hydrogen and helium, he says, should meet the single

Steve Nadis, *a frequent* Astronomy *contributor, keeps tabs on astrophysics advances from his home in Cambridge, Massachusetts.*



THE HUBBLE SPACE TELESCOPE (HST) and many ground-based telescopes detected an optical source at the same location as the May 9, 2005, gamma-ray burst. This was the first time astronomers observed a short GRB's afterglow in visible light. These images, which HST took 5.6, 9.8, 18.6, and 34.7 days after the burst, show the fading afterglow. DEREK FOX/PENNSYLVANIA STATE UNIVERSITY

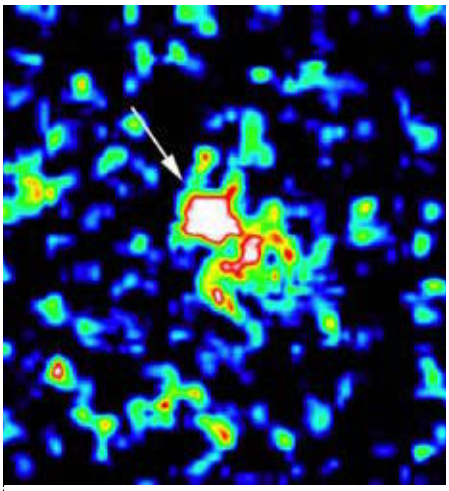
criteria for GRB progenitors: They would have been massive.

Woosley suggests these stars would remain compact in the end and rotate rapidly, thus satisfying two other key requirements. If anything, he says, "The first generation of stars were more likely to produce GRBs and more likely to produce bigger bursts than current stars."

What would the burst of such an early star look like? And how can we distinguish distant ones from nearby ones? These questions are not academic. The premier GRB-finding instrument, the Swift Gamma Ray Burst Explorer, has been circling our planet since November 2004, picking up a new burst once or twice a week on average.

We're looking for long-lasting bursts, explains Swift principal investigator Neil Gehrels of NASA's Goddard Space Flight Center, because the duration of an explosion, as seen by us, will have stretched because the universe itself has expanded.

As a result, the expansion changes the GRB's energy into high-energy X-rays.



THIS FLASH from a distant GRB doesn't appear to have a host galaxy. The Hubble Space Telescope caught the visible fireball May 8, 1997. ELENA PIAN/ANDREW FRUCHTER/NASA

Finally, the afterglow would be visible in infrared but not in optical wavelengths because a chunk of the electromagnetic spectrum literally disappears when clouds of neutral hydrogen gas still present in the early universe absorb it.

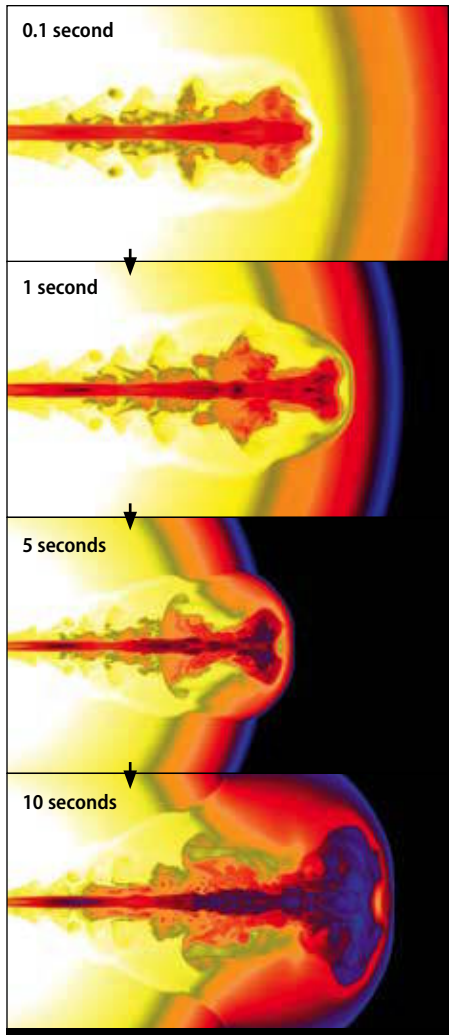
Negative confirmation

On September 4, 2005, University of North Carolina astronomer Dan Reichart and then-undergraduate student Josh Haislip came across a telltale pattern: An infrared instrument on Chile's SOAR telescope detected an afterglow from a burst (labeled GRB 050904) identified by Swift a few hours earlier. Meanwhile, a nearby optical array called PROMPT, which Reichart directs, saw no sign of an afterglow.

"When you find something in infrared and not optical, you've either found the most exciting thing imaginable — a distant burst — or something very dull, [like] dust along the line of sight," Reichart says. Subsequent analysis showed the cutoff in optical light was sharp, unlike the smoother cutoff expected if dust were the culprit.

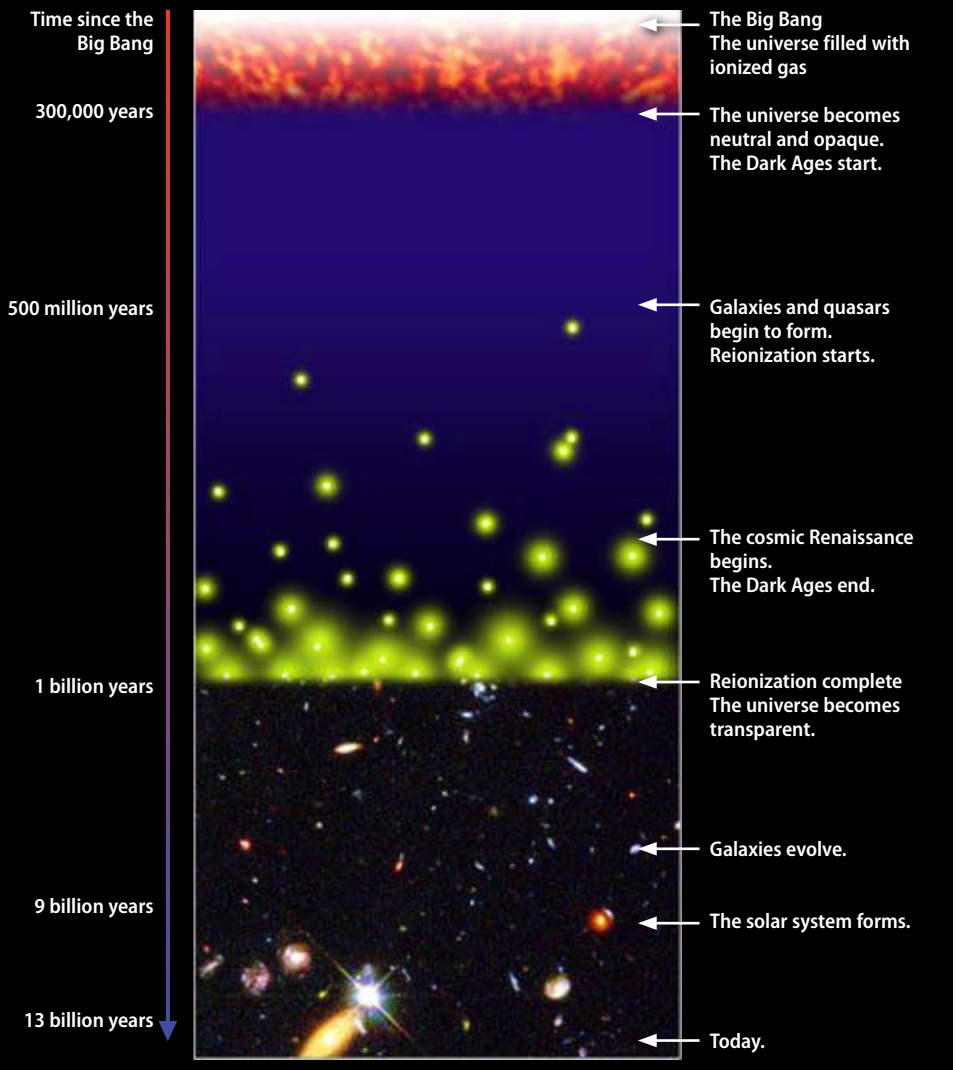
Three nights later, Japanese observers at the Subaru Telescope in Hawaii obtained a detailed spectrum of GRB 050904's afterglow. By measuring the wavelengths of absorption lines for various elements, the Japanese team put the burst's redshift at 6.295. This made it the most distant stellar explosion ever witnessed, according to Enrico Ramirez-Ruiz of UCSC. The burst, in other words, erupted less than 900 million years after the Big Bang.

"Light from a gamma-ray burst afterglow starts on its way to us about one light-year from the star of origin, through the host galaxy, and all the way across the universe to us at Earth," explains UCSC astronomer Jason Prochaska. "Any gas along the way can imprint a distinct signature, or fingerprint, on the light we observe, and

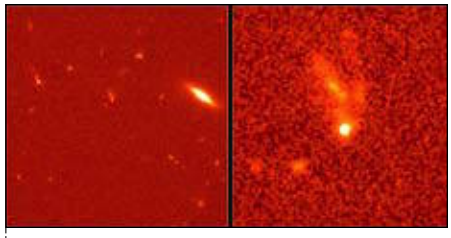


JETS OF of relativistic particles destined to become a gamma-ray burst force their way out of a massive star in this computer simulation. The jets tunnel through the star in about 10 seconds, and, along with a powerful wind of particles from the accretion disk, they destroy the star in a supernova. If the jets point within about 5° of Earth, observers will detect the highest-energy particles (yellow and orange) as a gamma-ray burst that lasts between 2 and 20 seconds. WEIQUN ZHANG/STAN WOOSLEY

What is the Reionization Era?

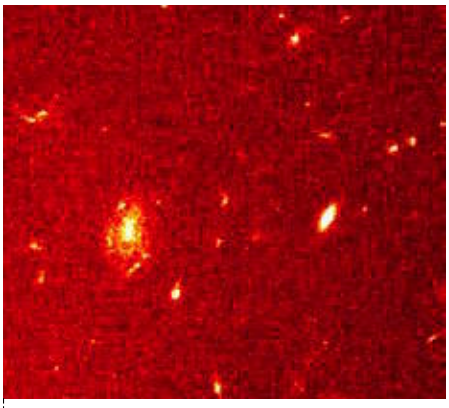


S. G. DJORGOVSKI ET AL. AND DIGITAL MEDIA CENTER, CALTECH



ANDREW FRUCHTER/NASA

THIS DISTANT BOOM — a gamma-ray burst exploding with the energy of 100 million billion stars — became visible January 23, 1999. Hubble's camera caught the event in a galaxy two-thirds of the way to the edge of the visible universe.



THIS GAMMA-RAY BURST set the brightness record. In 1997, astronomers using the Hubble Space Telescope imaged this GRB that was briefly as bright as the rest of the universe. GRB 971214, which lies about 12 billion light-years away, released 100 times more energy than astronomers previously thought possible. S. R. KULKARNI AND S. G. DJORGOVSKI/THE CALTECH GRB TEAM/NASA

from all these little fingerprints you can create an aggregate picture."

What GRBs tell us

Indeed, scientists extract a wealth of information from spectroscopic measurements. They scrutinized GRB 050904's host galaxy, for example, which they would never have known about had it not been for the burst. They looked at 10 to 15 different elements and, literally, counted the atoms of those elements that absorbed tiny chunks of GRB light. By comparing those numbers with metal abundances measured in the Milky Way, researchers determined how chemically enriched the host galaxy was — in this case at least the galaxy contains 10 percent of the Milky Way's metal content.

Astronomers also want to gauge the universe's degree of ionization at the time of the burst. They know the universe was fully reionized by redshift 6 (a billion years after the Big Bang). They also know GRB 050904 occurred before reionization was complete; it's the only stellar explosion for which that claim can be made. Investigators eagerly await more examples to help with the question of when reionization began. "If we can get a good reading at different redshifts, we can map out reionization and see how it progressed," says Reichart.

In the case of GRB 050904, astronomers were unlucky. They couldn't get a clear reionization measurement because the host galaxy was massive, shrouding the burst in a dense cloud of material. In general, higher-redshift bursts are likely to sit in smaller galaxies that have thinner clouds of light-absorbing hydrogen, thereby making such measurements easier.

Nevertheless, the GRB 050904 experience was still a successful "proof of concept," showing distant bursts can, indeed, be found. It also showed that, in principle, "the same spectroscopic techniques that enable us to measure metallicity also enable us to measure ionization," says Bromm. That's important because the universe goes through two fundamental transitions. It's neutral and pristine 400,000 years after the Big Bang and ends up ionized and chemically enriched. "And high-redshift GRBs may be the best way of seeing both of these things," says Bromm.

Investigators now hope that GRBs can provide a deeper and less distorted view of the universe than the previous standard-bearers, quasars. Because GRBs are short-lived, they affect their surroundings to a radius of only about 10,000 light-years. Quasars, by contrast, affect the environment to a radius of about 10 million light-years. They are, in Bromm's opinion, a "blunt instrument because they disturb the very properties you want to measure."

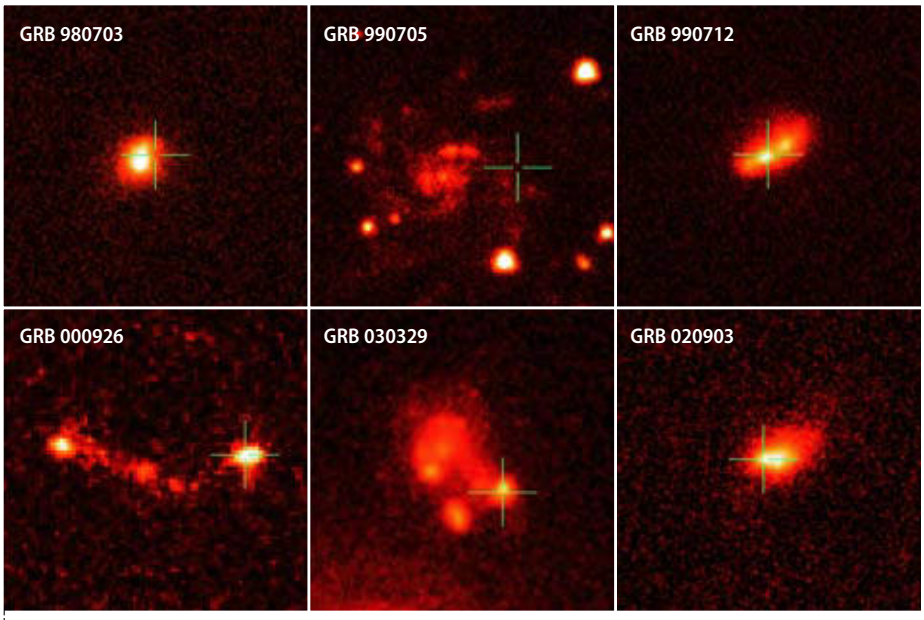
Searching for old bursts

Astronomers need to realistically temper their enthusiasm for GRB cosmology. For one thing, astronomers don't know why Swift had discovered only one burst beyond redshift 6. As of mid-2007, astronomers have computed redshifts for 60 long bursts, but none beyond redshift 6. "After two-and-a-half years of data, Swift is telling us this is a tough game to play," notes Reichart.

"Swift is also telling us there aren't enough resources on the ground to track down GRBs at high redshifts," adds University of California Berkeley astronomer Joshua Bloom. The main shortage is in infrared (IR) telescopes, which are necessary to study the afterglows of distant bursts invisible in optical wavelengths. Astronomers suspect they've missed a number of high-redshift GRBs as a result. To help redress this deficiency, Bloom is using PAIRITEL, a robotic, 1.3-meter infrared telescope on Mount Hopkins in Arizona, operating in concert with Swift, to follow up on GRB detections.

PAIRITEL, the world's largest telescope devoted to transient IR events, can get to bursts within a minute of when Swift finds them, Bloom says. "But as we're just a single observatory on a single site that's subject to weather, only about 10 percent of the Swift events are observable to us." That's why Bloom is trying to establish a worldwide network of autonomous infrared telescopes that can talk to each other and to Swift.

NASA'S SWIFT SATELLITE, launched in November 2004, continues to locate gamma-ray bursts (GRBs). The satellite has detected several thousand GRBs and imaged many of their afterglows using onboard optical, ultraviolet, and X-ray telescopes. NASA/SPECTRUM ASTRO



GRB HOST GALAXIES were part of a study that compared the environments of long- and short-duration GRBs. The crosshairs pinpoint the GRBs. Hubble's Wide Field Planetary Camera 2 took the images between 1999 and 2005. The galaxies lie between 2 and 10 billion light-years away. NASA/ESA/ANDREW FRUCHTER (STScI)/THE GRB OPTICAL STUDIES WITH HST (GOSH) COLLABORATION

But what about Swift? What can it do to capture more distant GRBs? Swift scientists have, in fact, designated 2008 as "the year of the high-redshift bursts." Plans call for lowering the detection threshold on Swift's Burst Alert Telescope (BAT). "The idea is that the really distant bursts must be below our threshold, so hopefully we can pick up some of those," explains Gehrels (albeit at the cost of more false alarms).

To facilitate ground-based observations, astronomers will point BAT toward parts of the sky that have large telescopes underneath. In addition, Swift planners have begun pointing their telescope toward the middle of the night sky so astronomers on the ground will have more time to follow up on detections.

"You can't expect the ground-based observing community to drop what they're doing and check out two bursts a day," says Jonathan Grindlay, the mission's principal investigator. "But if we can claim a high probability of redshift 7 or higher, we can get the ultimate telescope to look at it, the James Webb Space Telescope."

EXIST would be a "discovery engine" for JWST by identifying high-redshift galaxies for JWST to look at, adds Bloom, a member of the mission's planning team. "Because of GRBs, we'd know this is a special place in the universe."

With EXIST and JWST working together, Grindlay suggests, "We'd try to drill as many lines of sight in the sky as possible, figuring out where galaxies lie along these lines of sight. Eventually we could begin to map in three dimensions the high-redshift universe." Because it will take many lines of sight to do that, he notes, an initial goal is simply to build up statistics.

Setting future goals

How many high-redshift bursts do we need to construct a clear cosmological picture? "Obviously the more the better," says Gehrels. "Right now we have just one burst beyond redshift 6, and that's clearly not enough because that one could be unusual. Ten events is where you start to see trends in metallicity and ionization, which is why we've been trying our hardest to find those distant bursts." Nevertheless, Gehrels admits, the observational effort has been frustrating at times.

Bromm, however, is not dismayed by the fact that Swift has turned up only one GRB beyond redshift 6. "With any new technique, there's always a learning curve in the beginning — a period of trial and error," he says. "These are still the early days, and I'm quite optimistic about the prospects. We still have to get lucky, of course, but fortune favors the prepared mind."

WEB EXTRA Explore an animation that shows how a gamma-ray burst works at www.Astronomy.com/toc.

How we junked up

Derelict spacecraft, stray nuts and bolts, and millions of even tinier fragments litter the space around Earth. /// BY RICHARD TALCOTT

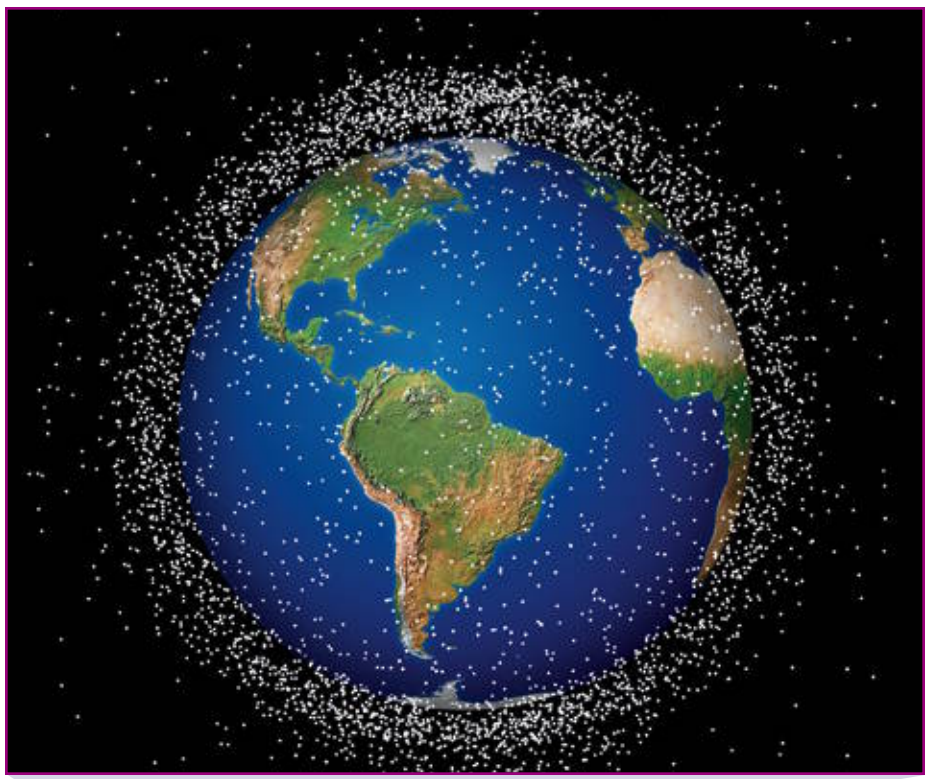
On January 11, 2007, space got a lot more crowded. The population of "space junk" — manmade objects in Earth orbit that no longer serve a useful purpose — literally exploded that day, when the People's Republic of China blew up one of its Earth-orbiting satellites. This successful test of a Chinese anti-satellite system created more space debris than any event in history. It also marked the opening volley in what proved to be the worst year yet for polluting near-Earth space.

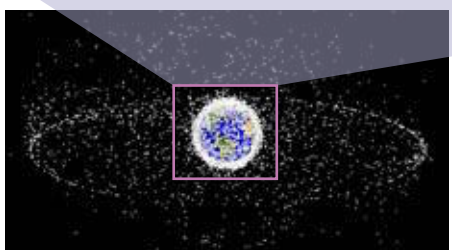
Space debris has been a growing problem for 50 years. The oldest piece of space junk belongs to the United States. The Vanguard 1 spacecraft — an aluminum sphere just 6.5 inches (16.5 centimeters) across and weighing 3.24 pounds (1.47 kilograms) — was launched in March 1958 and ceased operations in May 1964. It's been orbiting Earth silently ever since, and will continue to do so for centuries.

It now has plenty of company. The roster of space debris includes everything from non-operational satellites (like Vanguard) and spent rocket boosters to paint flakes and explosion fragments. The amount of junk now circling Earth totals thousands of tons. And it poses a significant threat to all still-functioning satellites, including the space shuttle and the International Space Station.

A pair of big bangs

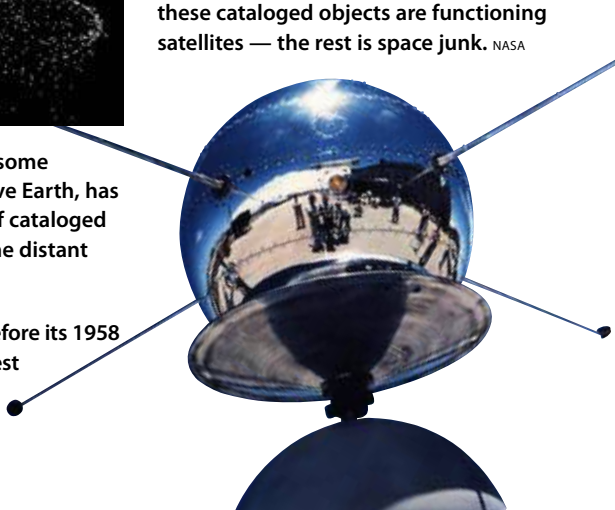
As 2006 drew to a close, The U.S. Space Surveillance Network (SSN) was tracking some 9,949 pieces of debris. But, at that time, the 8-year-old Chinese meteorological satellite Fengyun-1C was in one piece. On January 11, 2007, a ballistic missile





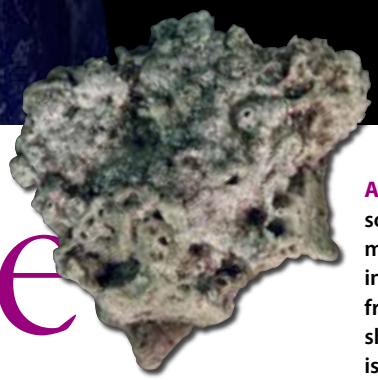
▲ THOUSANDS OF OBJECTS (shown as white dots) fill low Earth orbit, the region of space within 1,243 miles (2,000 km) of Earth's surface. Less than 10 percent of these cataloged objects are functioning satellites — the rest is space junk. NASA

GEOSYNCHRONOUS ORBIT, some 22,300 miles (35,890 km) above Earth, has the second-highest number of cataloged objects. It shows up here as the distant ellipse of dots. NASA



▶ VANGUARD 1, seen here before its 1958 launch, now stands as the oldest piece of orbital debris. NASA

outer space



ALUMINUM-OXIDE SLAG from solid-rocket motors may create much of the inch-sized debris in orbit. This piece, recovered from a test firing of the space shuttle's solid-rocket booster, is shown at actual size. NASA

launched from Xichang, China, slammed into the 2,120-pound (960 kg) spacecraft at approximately 20,000 mph (32,000 km/h). The satellite disintegrated and spread its debris throughout low Earth orbit and beyond.

One year later, the SSN had cataloged 2,317 fragments, and tentatively identified 250 more. (The network's ground-based radar can track only objects bigger than 4 inches [10cm] across, on average.) Of the fragments, only 22 had reentered Earth's atmosphere. Scientists with NASA's Orbital Debris Program estimate the explosion created at least 150,000 pieces of debris 0.4 inch (1cm) or larger.

Although Fengyun-1C orbited at an average altitude of 532 miles (855 km), the debris dispersed rapidly. The debris cloud now encircles Earth and extends from 125 to 2,485 miles (200 to 4,000 km). A majority of the debris travels on long-duration orbits and will survive decades or longer.

Fengyun-1C's debris significantly increases the possibility of collisions with spacecraft in low Earth orbit. On June 22, 2007, NASA had to maneuver its Terra environmental satellite to avoid a fragment destined to pass just 62 feet (19 meters) away.

Unfortunately, the Chinese ASAT test wasn't the only big debris maker of 2007. On February 19, a Russian Briz-M booster stage exploded into more than 1,000 detectable pieces. The 2-ton booster had malfunctioned a year earlier, when it failed to place an Arabsat 4A spacecraft into its proper orbit.

The unused propellants remaining on board likely triggered the accidental blast. The good news: The debris field orbits at a much lower altitude than that from Fengyun-1C, so most of the fragments should burn up in the atmosphere relatively soon.

Contrast these two events with America's downing of the USA-193 spy satellite February 20. The intercept happened at such a low altitude (153 miles [246 km]) that more than half the debris entered the atmosphere within 45 minutes, and more than 99 percent fell out of orbit within a week. Most of the rest is now gone as well.

A big problem

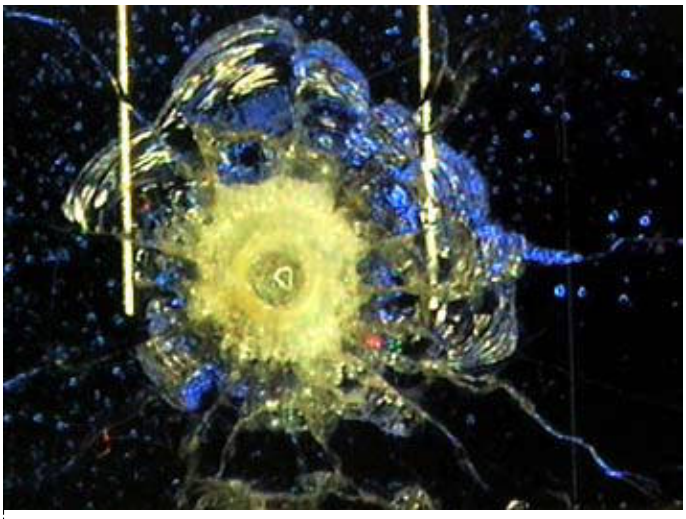
The same can't be said for the rest of the orbital debris. As of January 1, 2008, the SSN cataloged 12,456 objects in orbit. Of these, approximately 800 (6 percent) are operating spacecraft. This leaves more than 11,500 pieces of orbital debris about 4 inches (10cm) in diameter and larger.

Most of this debris lies in low Earth orbit (below an altitude of 1,243 miles [2,000 km]). It's not spread evenly, however. Major concentrations occur at altitudes near 500 miles (800 km), 620 miles (1,000 km), and 930 miles (1,500 km). Far less debris exists in geosynchronous orbit, 22,300 miles (35,890 km) above Earth.

Richard Talcott *is a senior editor of* Astronomy.

A TITANIUM MOTOR CASING from the third stage of a Delta 2 rocket reentered Earth's atmosphere January 21, 2001. The casing, which weighs about 155 pounds (70 kg), survived reentry and landed in Saudi Arabia. NASA

RADAR OBSERVATIONS from these Haystack Observatory instruments in Tyngsboro, Massachusetts, help NASA track inch-sized orbital debris. The radars spend approximately 600 hours each year on this project. NASA



A CLOSE-UP LOOK at a Hubble blemish 0.1 inch (2.5mm) across shows the damage caused by even a small impact. ESA

At this altitude, ideal for some communications and environmental satellites, a satellite remains above a fixed point on Earth.

Altitude plays the key role in how long the debris remains in orbit. At altitudes below 125 miles (200 km), debris will fall out of orbit in just a few days. At altitudes between 125 and 375 miles (200 and 600 km), debris will survive for a few years. A piece's lifetime balloons to decades if it orbits between 375 and 500 miles (600 and 800 km). Any objects higher than that in low Earth orbit will last for centuries. Debris in geosynchronous orbit will remain there essentially forever.

On average, about 1 cataloged object falls from orbit each day. Most such pieces burn up in the atmosphere, but a few survive to the surface. Perhaps the most spectacular incident occurred in 1979, when the Skylab space station broke up on reentry and pieces fell over the Indian Ocean and Western Australia. So, what are the odds of someone on Earth being injured by a falling piece of debris? About 1 in a trillion. That's roughly a million times less than the risk of being struck by lightning in the United States.

The quantity of debris skyrockets as you go to smaller sizes. Several hundred thousand pieces between 0.4 and 4 inches (1 and 10cm) in diameter probably exist. And researchers calculate the number of particles smaller than 0.4 inch (1cm) to be in the tens of millions.

Ground-based radar and optical telescopes typically find debris larger than 0.2 inch (0.5cm) wide. The SSN tracks only those bigger than 4 inches (10cm) across so spacecraft can maneuver away. Scientists can't predict the orbits of smaller objects accurately.

For the smallest particles, researchers estimate the numbers based on impacts recorded by spacecraft. The shuttle, the International Space Station, and the Hubble Space Telescope all sample the low-Earth-orbit environment as they fly through it. But the most valuable information came from NASA's Long Duration Exposure Facility. This spacecraft spent more than 5 years getting pummeled by debris. When the shuttle brought it back to Earth, its exposed surfaces revealed the hazards orbiting spacecraft face.

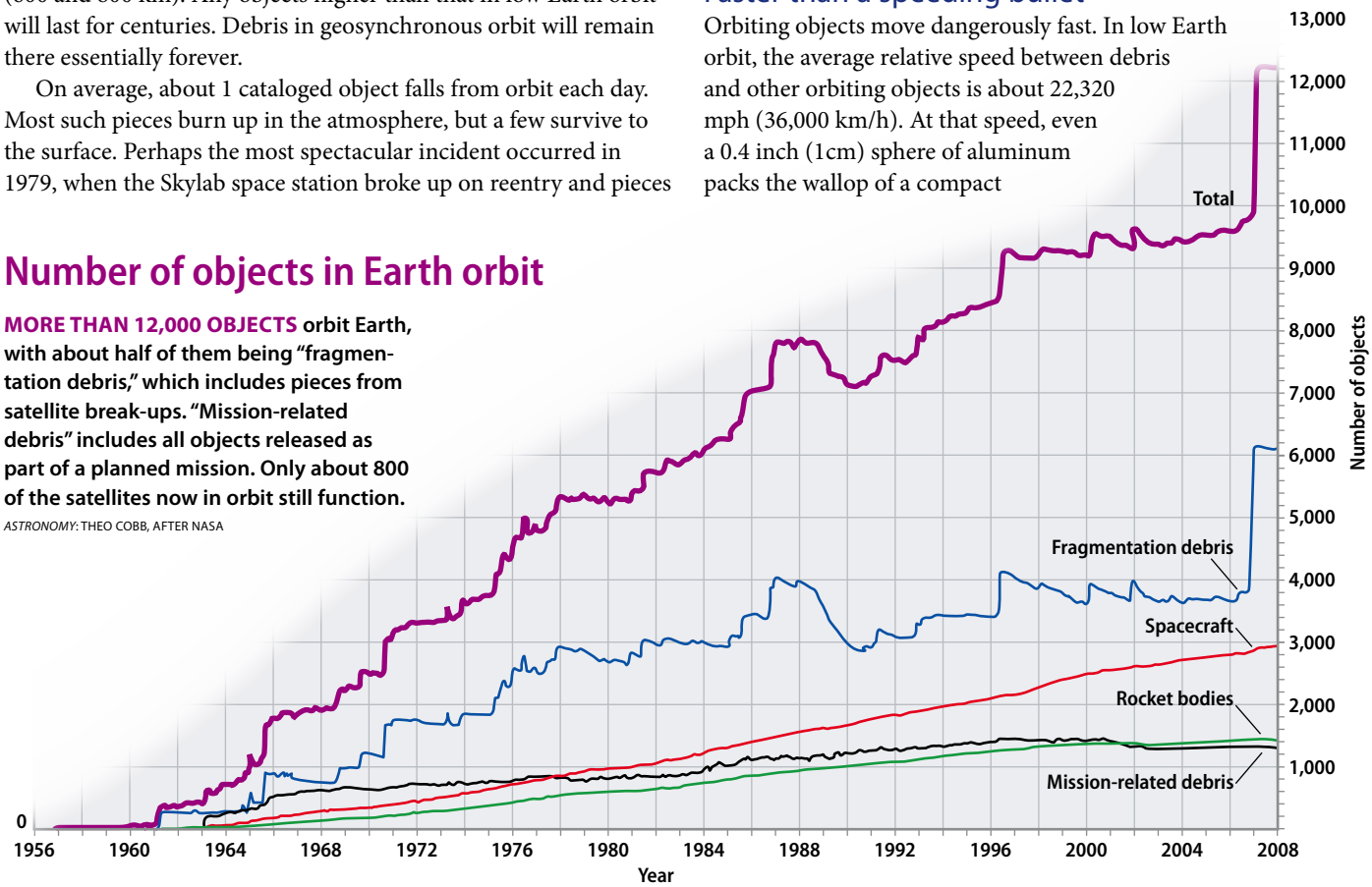
Faster than a speeding bullet

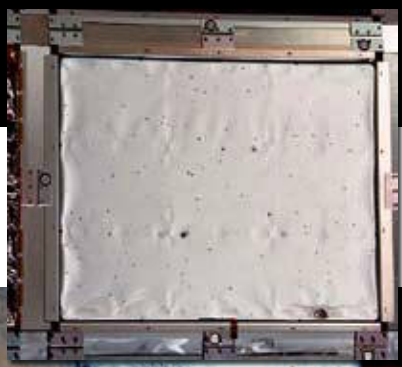
Orbiting objects move dangerously fast. In low Earth orbit, the average relative speed between debris and other orbiting objects is about 22,320 mph (36,000 km/h). At that speed, even a 0.4 inch (1cm) sphere of aluminum packs the wallop of a compact

Number of objects in Earth orbit

MORE THAN 12,000 OBJECTS orbit Earth, with about half of them being "fragmentation debris," which includes pieces from satellite break-ups. "Mission-related debris" includes all objects released as part of a planned mission. Only about 800 of the satellites now in orbit still function.

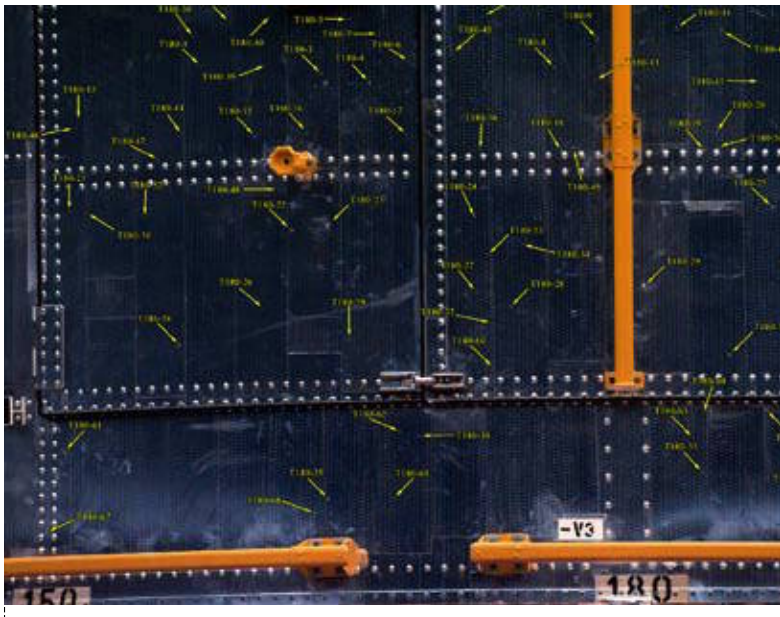
ASTRONOMY: THEO COBB, AFTER NASA





ONE LDEF PANEL (3 by 4 feet) records dozens of particle hits. NASA

THE SPACE SHUTTLE captures the Long Duration Exposure Facility (LDEF) in January 1990. Once back on Earth, scientists examined LDEF's panels to see what damage orbital debris can do. NASA

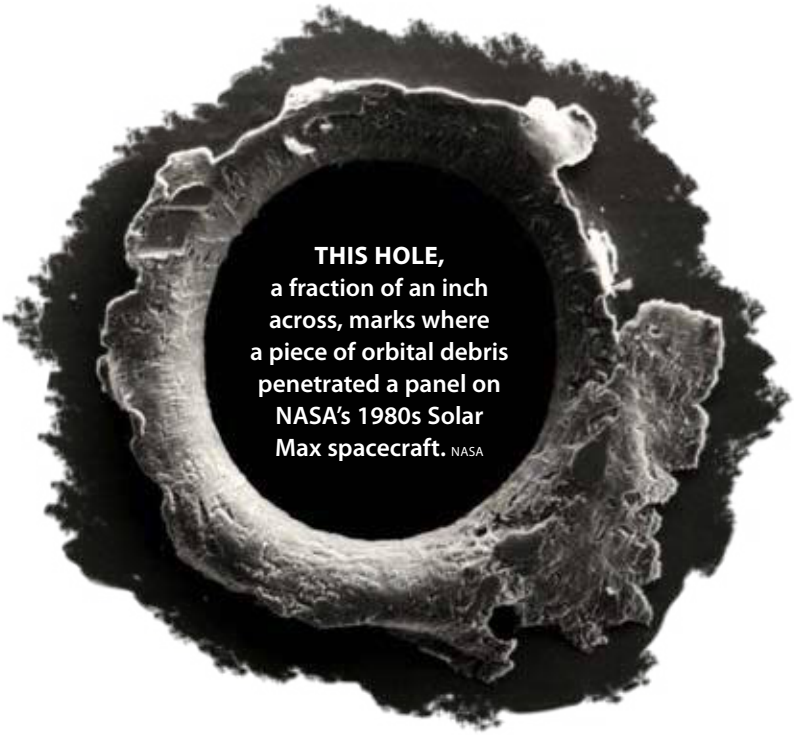


A SOLAR ARRAY from the Hubble Space Telescope shows plenty of dings from orbital debris. Shuttle astronauts returned this array to Earth for inspection. ESA

car traveling at 55 mph (89 km/h). In a head-on collision, the relative speed jumps to nearly 36,000 mph (58,000 km/h).

Although objects smaller than 0.04 inch (0.1cm) typically won't penetrate a spacecraft, those between 0.04 and 4 inches (0.1 and 10cm) will break through and cause damage. And anything over that size likely would trigger catastrophe. Luckily, such a massive collision has happened only once in Space Age history.

In 1996, the French communications satellite CERISE was hit by a briefcase-sized fragment of a European Ariane rocket. The collision severed the satellite's stabilization boom, but, amazingly, CERISE survived and continued to function (although its onboard computer had to be reprogrammed to control the craft's attitude).



THIS HOLE, a fraction of an inch across, marks where a piece of orbital debris penetrated a panel on NASA's 1980s Solar Max spacecraft. NASA

Creating a safer space

Humans created space junk, but can we get rid of it? Cleaning near-Earth space isn't an option. Although the world's space agencies would need to remove only large pieces — which create the small ones — it's too difficult and costly to rendezvous with this junk.

To limit orbital debris, an ounce of prevention is worth tons of cure. Stopping satellite explosions is the key step. Space agencies can vent or burn any fuel remaining in their rockets. Such a move would have prevented last year's Briz-M explosion.

Removing older satellites from orbit also helps. NASA controlled the Compton Gamma Ray Observatory's reentry into Earth's atmosphere in June 2000. Most of the massive spacecraft burned up through friction, and surviving pieces fell harmlessly into the Pacific Ocean.

Less drastic measures simply require maneuvering an aging spacecraft lower, where atmospheric drag will hasten its reentry. Such tactics won't work for satellites in geosynchronous orbit, however. When those spacecraft reach the ends of their useful lives, most get boosted into so-called graveyard orbits located some 185 miles (300 km) farther out.

Unfortunately, as long as we're a spacefaring civilization, space junk will be with us. We shield the space shuttle and International Space Station from smaller debris, and track bigger debris so spacecraft can maneuver around it. Still, near-Earth space is not a risk-free zone. For humans as well as spacecraft, vigilance pays the greatest dividends. A

WEB EXTRA To watch an animation of orbital debris' growth during the past half century, visit www.Astronomy.com/toc.

BY MARTIN RATCLIFFE AND ALISTER LING

JUNE 08

Three planets brighten June nights

Mars and Saturn adorn June's

western evening sky. Mars, a relatively tiny nearby world, contrasts nicely with distant, giant Saturn and its wonderful rings. The king of the planets, Jupiter, rises during early evening and dominates the sky all night, although it maintains an unusually low altitude.

The solar system's two other giants, Uranus and Neptune, are fine binocular targets. You can catch them easily despite the month's short nights, which limit dark-sky observing.

Six months after **Mars**' December 2007 opposition, Earth has left the Red Planet far behind. If we could view the solar system from above Earth's orbital plane, we'd find our planet leads Mars by about 90°.

With a telescope of sufficient size (10-inch aperture) and steady sky conditions, you'll be able to spot the Red Planet's distinctly gibbous disk. The downside: The Red Planet now spans only 5".

While diminutive in its telescopic appearance, Mars displays a nice orange hue that provides a pleasing contrast with bluish-white Regulus, the brightest star in Leo the Lion.

Mars starts the month in Cancer the Crab and crosses into Leo June 10. Track the Red Planet's nightly motion. You'll see Mars close within 43' of Regulus by June 30. Mars is slightly fainter than the 1.4-magnitude star.

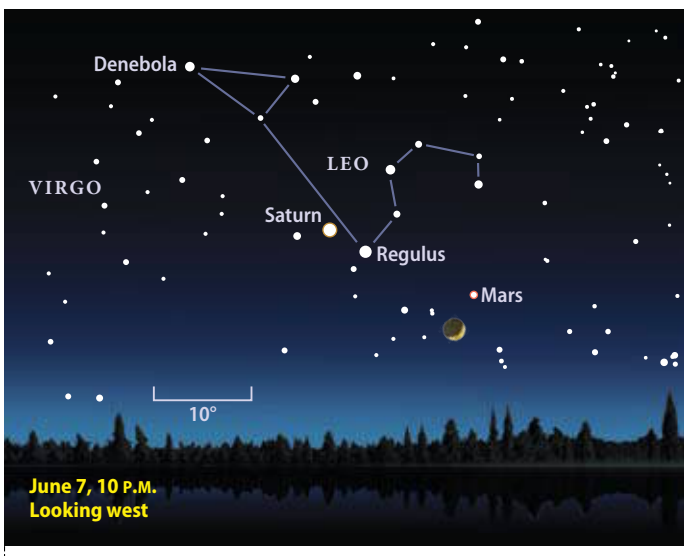
Less than 5° east of the pair stands Saturn, adding its yellowish hue to the darkening summer sky.

— *Continued on page 49*

SATURN AND MARS (left) met in Cancer in June 2004. The pair mirrors the bright stars Castor and Pollux in Gemini, which appear at right. This year, Saturn and Mars meet in Leo. PAUL SMITH

44 Mars, Saturn meet the Moon
49 Catch Boötid meteors
49 See a lunar crater, a peak, and a wrinkle
50 View Ganymede transit Jupiter
50 A comet meets M4
51 Spot asteroid 3 Juno
51 See a Saturn moon "pileup"

Visible to the naked eye
Visible with binoculars
Visible with a telescope

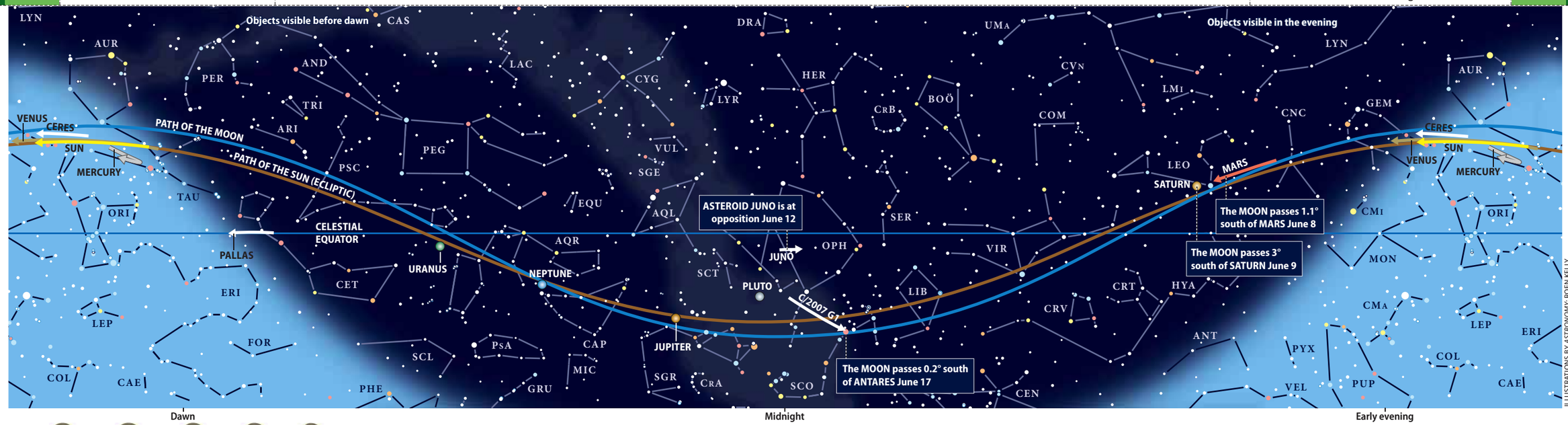


THE MOON JOINS Saturn, Mars, and Regulus June 7. Look for the waxing crescent Moon, with the Red Planet hovering near it, low in the west at 10 P.M. local daylight time. *ASTRONOMY:* THEO COBB

Planets in June

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

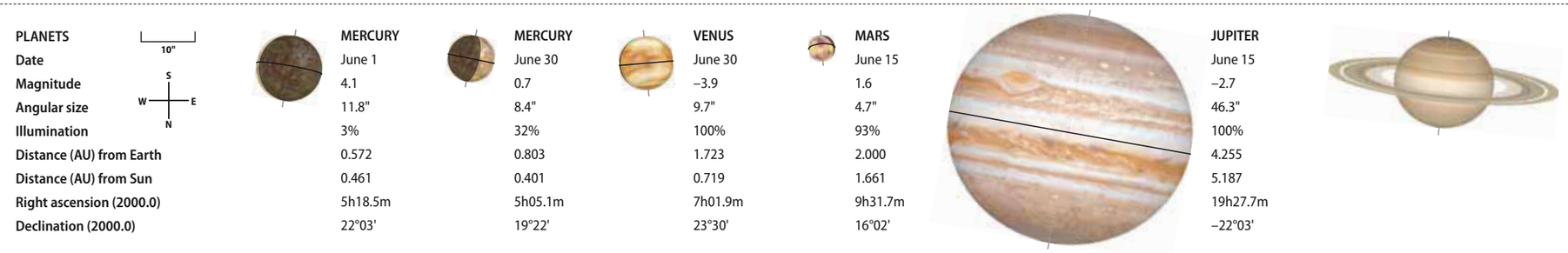
Astronomy magazine



ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

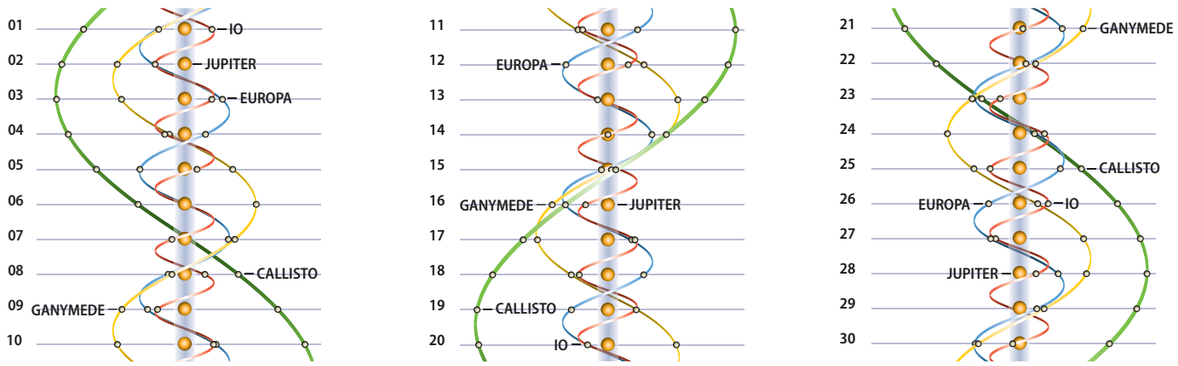
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	June 1	June 30	June 30	June 15	June 15	June 15	June 15	June 15	June15
Magnitude	4.1	0.7	–3.9	1.6	–2.7	0.8	5.8	7.9	13.9
Angular size	11.8"	8.4"	9.7"	4.7"	46.3"	17.3"	3.5"	2.3"	0.1"
Illumination	3%	32%	100%	93%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.572	0.803	1.723	2.000	4.255	9.623	20.042	29.516	30.472
Distance (AU) from Sun	0.461	0.401	0.719	1.661	5.187	9.311	20.098	30.039	31.477
Right ascension (2000.0)	5h18.5m	5h05.1m	7h01.9m	9h31.7m	19h27.7m	10h22.7m	23h34.5m	21h45.7m	17h59.4m
Declination (2000.0)	22°03'	19°22'	23°30'	16°02'	–22°03'	11°57'	–3°42'	–13°49'	–17°02'



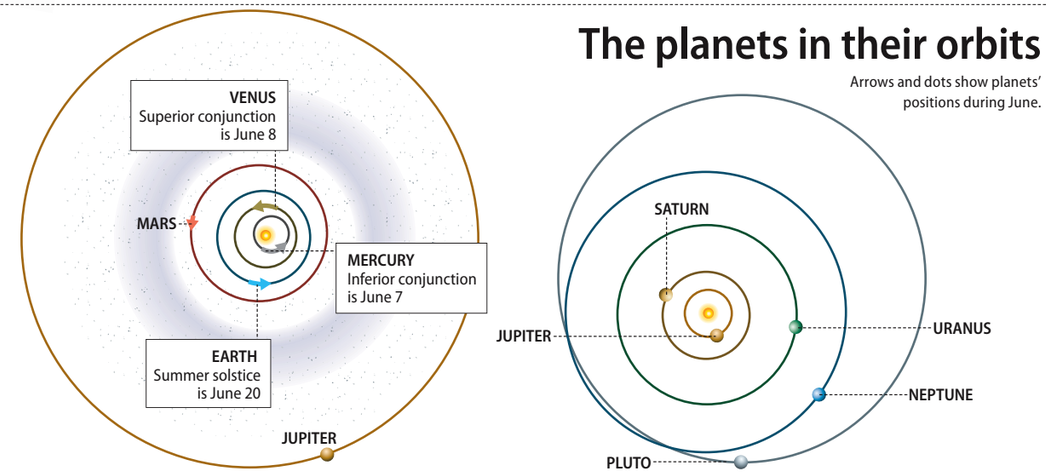
Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view through a telescope.



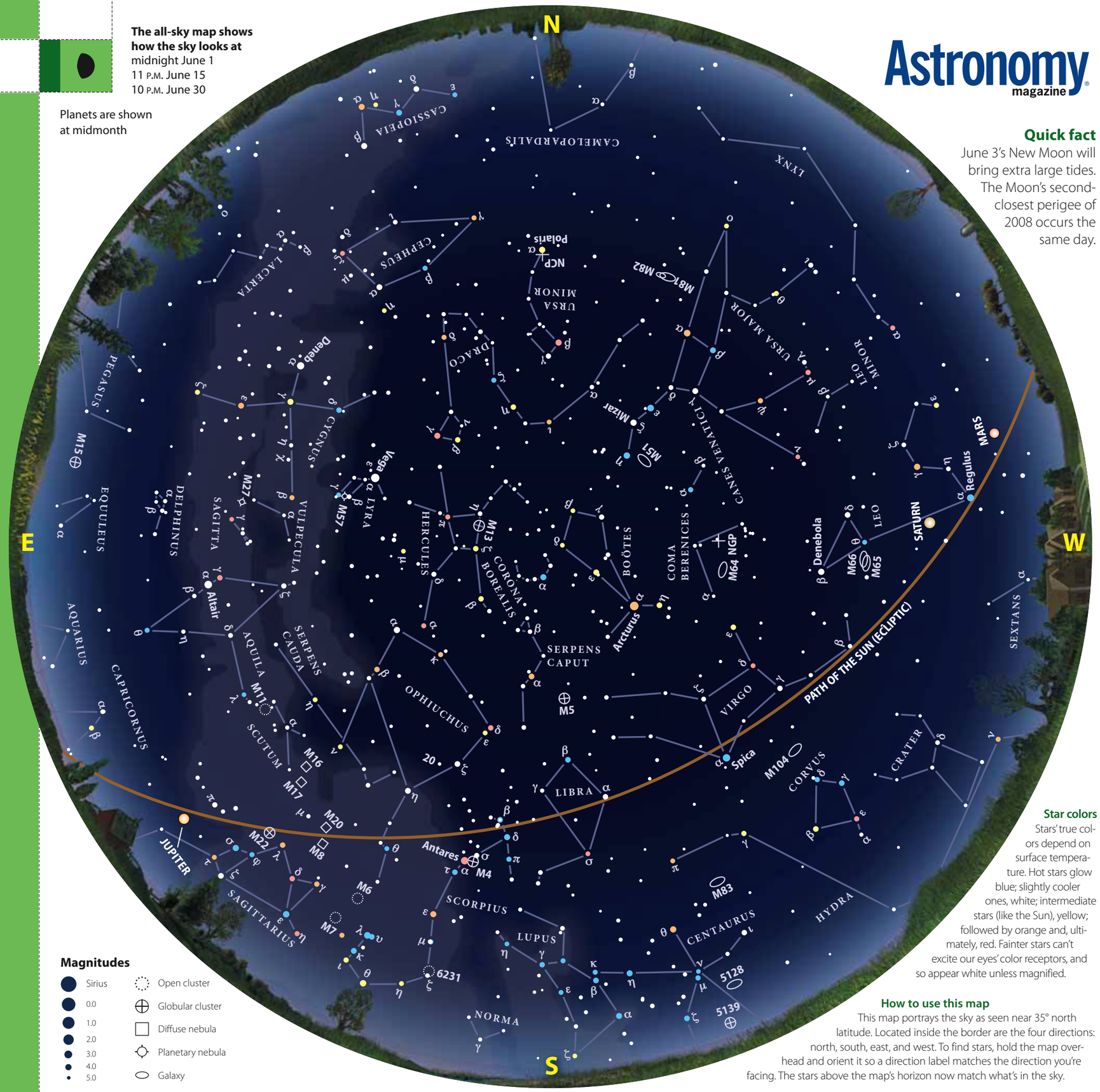
The planets in their orbits

Arrows and dots show planets' positions during June.



The all-sky map shows how the sky looks at
midnight June 1
11 P.M. June 15
10 P.M. June 30

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Star colors
Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map
This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Astronomy magazine

Quick fact
June 3's New Moon will bring extra large tides. The Moon's second-closest perigee of 2008 occurs the same day.

NOTABLE OBSERVING DATE:
June 26: The Boötid meteor shower peaks at 10:30 P.M. EDT

june 08

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
[01]	[02]	[03]	[04]	[05]	[06]	[07]
[08]	[09]	[10]	[11]	[12]	[13]	[14]
[15]	[16]	[17]	[18]	[19]	[20]	[21]
[22]	[23]	[24]	[25]	[26]	[27]	[28]
[29]	[30]					

03 The Moon is at perigee (221,985 miles from Earth), 9:21 P.M. EDT

New Moon occurs at 3:23 P.M. EDT

07 Mercury reaches inferior conjunction, 11 A.M. EDT

The Moon passes 1.1° south of Mars, 10 P.M. EDT

08 Venus reaches superior conjunction, midnight EDT

09 The Moon passes 3° south of Saturn, 5 A.M. EDT

10 First Quarter Moon occurs at 11:04 A.M. EDT

12 Asteroid Juno reaches opposition, noon EDT

16 The Moon is at apogee (252,419 from Earth), 3:33 P.M. EDT

17 The Moon passes 0.2° south of Antares, 1 A.M. EDT

18 Full Moon occurs at 1:30 P.M. EDT

20 The Moon passes 2° south of Jupiter, 9 A.M. EDT

Summer solstice occurs at 7:59 P.M. EDT

23 The Moon passes 0.8° north of Neptune, 5 A.M. EDT

25 The Moon passes 4° north of Uranus, noon EDT

26 Last Quarter Moon occurs at 8:10 A.M. EDT

Boötid meteor shower peaks, 10:30 P.M. EDT

27 Uranus is stationary, 4 A.M. EDT

28 Asteroid Ceres is in conjunction with the Sun, 1 P.M. EDT

30 Mars passes 0.7° north of Regulus, midnight EDT

WEB EXTRA For definitions of terms, visit www.Astronomy.com/glossary.

— *Continued from page 44*

The colors of planets and stars are subtle. They become most obvious when two objects of differing hues lie close together in the sky. That's exactly what observers get in late June, as Mars, Regulus, and Saturn gather together.

Delicate hue changes occur during sunset and dusk; in fact, colors change every minute after sunset. Watch the sky closely as darkness descends and this star-and-planet trio emerges into view.

A crescent Moon wanders 1.8° south of Mars June 7. By the next night, the Moon has crossed a 14° gap to reach a point 2° south of Regulus.

Saturn lies 4° above the Moon the same night. Now glowing at magnitude 0.8, the ringed planet outshines both Mars and Regulus.

Seeing Saturn in a telescope is a highlight of summer viewing. Rapid rotation bulges the planet's equator outward, which gives Saturn's disk an obvious flattened look. Saturn spans 17" in its equatorial diameter, but 15" pole to pole.

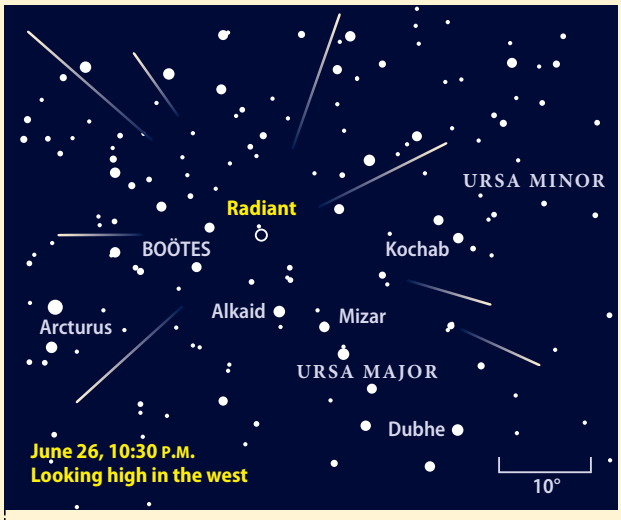
Saturn's atmospheric features are notoriously subtle. Observing them requires special filters to pull out detail. Occasionally, an obvious white spot appears on the planet's wan disk. This signifies the rare development of a major storm system. In 1990, the then newly launched Hubble Space Telescope imaged the last prominent white spot. In 2006, though, observers recorded less-pronounced spots.

Be prepared for a dramatic change in the appearance of Saturn's rings. For the next 2 months, they tip about 9° to our line of sight. In early September, Saturn passes through conjunction with the Sun and can't be observed. But when it emerges in the morning sky later that month, its rings will tilt 5°. This shrinks to less than 1° by year's end.

What's happening? Earth will pass through Saturn's ring plane in 2009. This will be the first time in 13 years Earth has made such a crossing. The rings are so thin, they disappear from view in anything other than a large telescope.

Saturn's largest moon, Titan, is easy to spot in small telescopes; dimmer moons represent more of a challenge, but they're easy in scopes with apertures of 8 or more inches. Titan passes closest to Saturn when it passes north of the planet, as on June 13 and 29.

Martin Ratcliffe *is the author of* State of the Universe 2008 *(Praxis, 2007).* **Alister Ling** *is a meteorologist for Environment Canada.*



IS THERE A BOÖTID BLAST in your future? Outbursts from the June Boötids occurred in 1998 and 2004. There's another opportunity June 26/27. *ASTRONOMY:* THEO COBB

MONITOR METEORS FROM BOÖTES

June isn't known for meteors, but astronomers are keeping a watchful eye on the June Boötids. This little-known shower is linked to Comet 7P/Pons-Winnecke; outbursts occurred in 1998 and 2004.

Observers should be on the lookout for Boötid "shooting-stars" from June 22 to July 3. Any potential outburst, however, will occur between 6:30 P.M. EDT June 26 and 5 A.M. EDT June 27, when Earth grazes the comet's debris trail. Check the International Meteor Organization's web site (www.imo.net) for updated details.

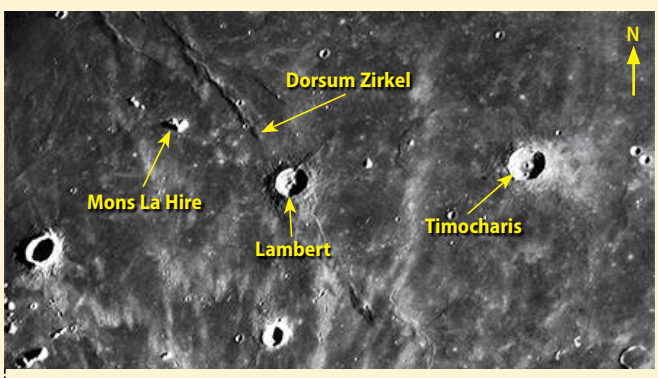
The shower radiant — the point from which meteors seem to fly — lies in the northern part of Boötes, which is visible nearly all night. The Last Quarter Moon, which rises around midnight, will wash out fainter meteors.

SEE A LUNAR CRATER, A PEAK, AND A WRINKLE

West of the Moon's spectacular lava-flooded crater Archimedes, the smaller gouges of Timocharis and Lambert craters stand out atop Mare Imbrium's lava plain. Lambert comes into view June 12. It casts a long shadow that extends into the lunar night.

Look south for the ghostly ring of Lambert R, a circular feature that's most likely a lava-buried crater. In a night or two, as the Sun climbs higher, Lambert R's thin shadows will disappear completely.

Mons La Hire is an isolated peak that catches the Sun's rays a full lunar day before its base does. Lunar scientists William K. Hartmann and Charles Wood proposed in 1971 that La Hire is related to Piton, Pico, and the other peaks on Mare Imbrium's north side. They suggested the peaks are the exposed portions of a buried mountain ring created by an ancient impact.

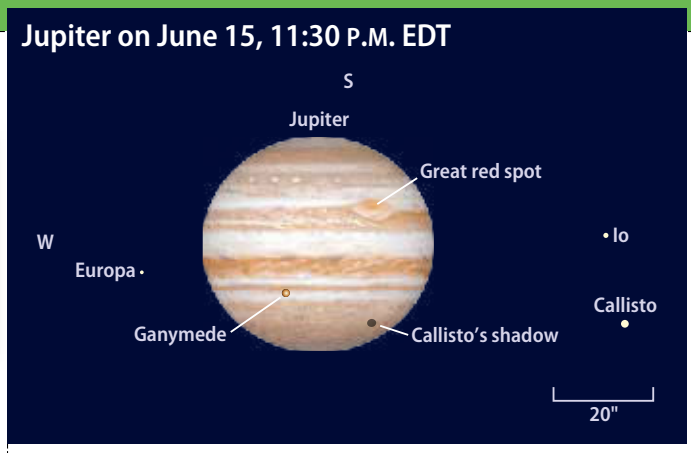


ON JUNE 12, a low Sun highlights Lambert Crater and the mountain peak of Mons La Hire. Subtle features like Dorsum Zirkel disappear as the Sun rises higher. *CONSOLIDATED LUNAR ATLAS* (LPL/UA)

However, the ring's presence creates ridges at the surface. One ridge segment, named Dorsum Zirkel, runs northwest of Lambert. This feature also disappears at high Sun angles, so don't wait to observe it.

/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (west)	Jupiter (southeast)	Mercury (east)
Mars (west)	Saturn (west)	Jupiter (south)
Saturn (west)		Uranus (southeast)
		Neptune (south)



CATCH A MOON, a shadow, and the Great Red Spot traveling across Jupiter's disk June 15. Callisto throws its shadow on Jupiter's clouds as Ganymede slips across the disk. South of them lies the Great Red Spot, a centuries-old storm. *ASTRONOMY*: THEO COBB

Look for Titan south of Saturn June 5 and 21.

Iapetus, the peculiar moon that appears brightest when farthest west of Saturn, fades throughout June. It lies north of the rings June 5 and 6, but at magnitude 11 it's tricky to spot. Iapetus reaches eastern elongation June 27 and dims by nearly a full magnitude (to 11.9).

As Saturn settles in the western sky, **Jupiter** rises in the southeast. Saturn sets ever earlier as June progresses, and Jupiter rises earlier each night. By June 30, the solar system's biggest planet shines 14° high 2 hours after sunset. On a moonless night, look for the Milky Way's glowing band in Sagittarius to the right of dazzling (magnitude –2.6) Jupiter.

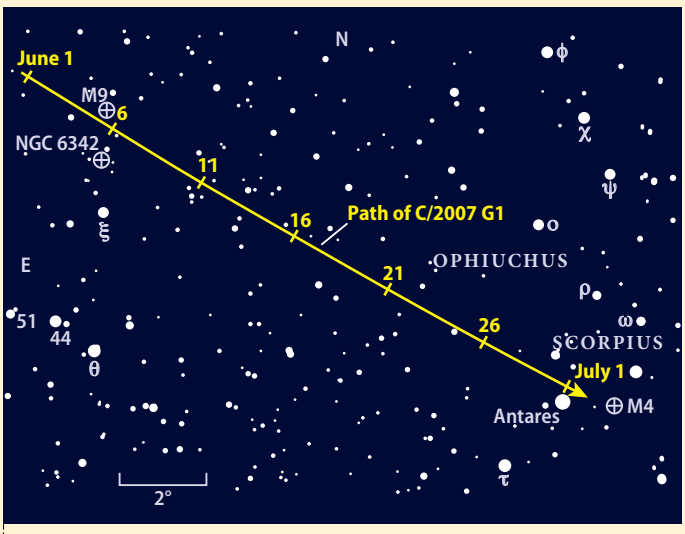
Jupiter reaches opposition in early July, so it's visible almost all night this month. For the best telescopic views, observe the planet around its culmination in the south, which places it at least 20° above the horizon. Much lower, and the turbulence in Earth's atmosphere blurs the disk's fine detail.

Jupiter's relatively large disk spans 47" by month's end, more than double Saturn's apparent diameter. Jupiter's atmospheric details show much higher contrast than Saturn's, which makes for more interesting observations. Dark features called belts appear most obvious.

The darkest of these are the North and South Equatorial Belts that straddle the planet's midsection. Last year, a jovian weather event disrupted the South Equatorial Belt. This produced changes telescopic observers could track nightly.

Jupiter's equatorial region rotates in 9 hours 50 minutes. Its northern and southern temperate regions take 5 minutes longer, which results in a 250-mph (400 km/h) difference in wind speed where the two regions meet. This boundary generates many of the eddies, spots, and festoons Jupiter is so well known for.

With practice, observers can detect changes in the location of these features within 5 or 10 minutes. The largest of the disturbances, the Great Red Spot,



COMET LINEAR (C/2007 G1) courses through Ophiuchus in June. Observers up for a challenge can try to locate the comet amid the region's faint globular clusters. *ASTRONOMY*: THEO COBB

COMET LINEAR FLIES TOWARD M4

This month's comet is a dark-sky challenge, but it's worth the effort. Astronomers expect Comet C/2007 G1 (LINEAR) to glow at magnitude 11.9 as it glides past many globular star clusters. Head out of the city during the first or last week of June to avoid the Moon's glare.

Wait until midnight to let the comet rise above atmospheric haze. Start in Ophiuchus with the magnitude 7.9 globular Messier 9. An 8-inch scope at high power should resolve its ancient stars.

A little more than a degree east lies the smaller, fainter globular NGC 6356. Scan south a degree to locate the even smaller and fainter NGC 6342 (mag. 9.8). Comet LINEAR will be tougher yet.

You probably won't see LINEAR at low power. Try magnifications greater than 200x. Use the chart with a faint red light (and keep your observing eye closed) to zoom in on its position. If you still can't see it, try tapping the scope: A faint blob that moves is easier to see.

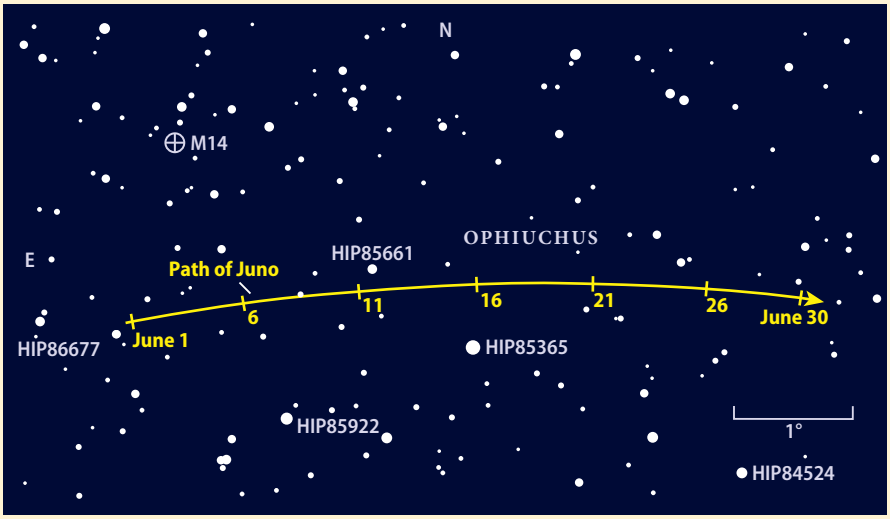
By month's end, LINEAR will slide between Antares and NGC 6144, a small globular near the giant cluster Messier 4. In fact, on July 2, LINEAR is only 10' from M4's core — perhaps all but hidden against myriad stars.

SPOT JUNO IN JUNE

Asteroid 3 Juno's elliptical orbit brings it closer to us in some years than in others. In 2009, Juno brightens to magnitude 7.6, but, this month, the space rock's peak brightness reaches only 10th magnitude. While that's within the grasp of a 4-inch scope, observers will need to put in some extra effort to locate it.

Begin your hunt in east central Ophiuchus. Start at the 4.5-magnitude star HD 157950, which you'll find on the all-sky map halfway between Beta (β) and Eta (η). This is your anchor star. Slowly slide your scope to Juno's position using background stars to confirm your heading.

Because Juno is so faint, casual observers will mistake it for a star. In fact, you may have to resort to an old-school imaging method: sketching. Locate Juno, then draw the stars you see in the field of view. Return to the field on another night to see which "star" moved.



ASTRONOMY: THEO COBB

German astronomer Karl Harding discovered Juno, which spans just 150 miles (244 km), September 1, 1804. Both the asteroid and the month of June get their names from Juno, Jupiter's wife in the Roman pantheon.

ASTEROID JUNO glides south of globular cluster M14 as the month opens. Pinpointing the magnitude 10 asteroid — and knowing you did so — will be an observing challenge.

typically is visible every other night from any location.

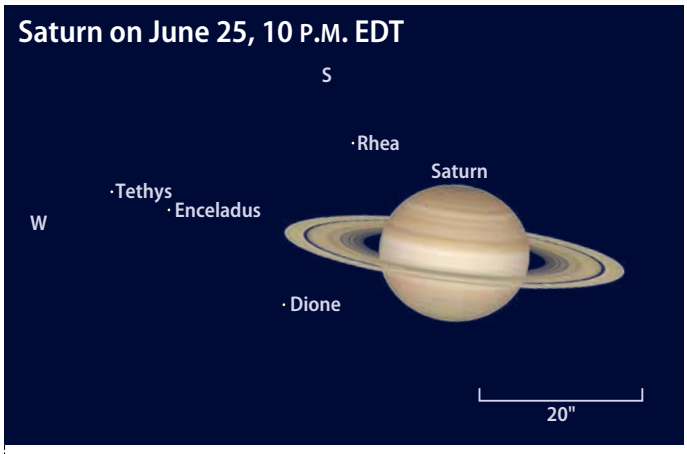
Io, Europa, Ganymede, and Callisto, the four so-called Galilean moons, are visible in any telescope as they wander east and west of Jupiter's disk. Occasionally, these moons pass in front of or behind the planet. A moon's shadow is one of the darkest features observers can see on Jupiter. Just a few minutes of viewing will reveal the shadow's motion. Sequential digital images of such shadow transits create interesting time-lapse movies.

Pluto reaches opposition June 20. The dwarf planet lies near 6 Sagittarii, a magnitude 6.2 star that makes an easy guide to Pluto's field. The star lies 2° north-northeast of the fine binocular open cluster M23 (NGC 6494). On June 1, Pluto lies 0.2° northwest of 6 Sagittarii. Pluto's retrograde motion carries it farther westward, and by month's end the dwarf planet is almost a full degree away from the star.

Pluto glows at magnitude 13.9. It remains the only one of hundreds of Kuiper Belt objects in similar orbits that's visible using amateur telescopes. Even so, detecting Pluto visually is a challenge, requiring perfectly transparent skies, a high-quality 8-inch scope — and preferably one 10 inches or larger — and a detailed star chart. You can find such charts in *The Observer's Handbook of the Royal Astronomical Society of Canada* or Guy Ottewell's *Astronomical Calendar*.

Neptune is 2 months from opposition. It's a binocular object shining at magnitude 7.9, and it's easy to locate north of Delta (δ) Capricorni, the easternmost star in Capricornus. Neptune forms a triangle with two stars, 42 Capricorni (magnitude 5.2) and 44 Capricorni (5.9). Neptune's disk spans 2.3". The planet rises before midnight by June 30.

Uranus is now a morning object. It stands high in the south a couple of hours before dawn. It lies in Aquarius, standing 5° east of Phi (φ) Aquarii at the eastern side of the constellation. The "circlet" of stars in Pisces lies to its north. Uranus shines at magnitude 5.8, an easy binocular target. Telescopes will reveal its greenish-blue tinged disk spanning 3.5".



SATURN'S MOONS Rhea, Tethys, and Dione act as guides for finding faint Enceladus June 25. That night, look for a moon "pileup" west of Saturn. ASTRONOMY: THEO COBB

Mercury reappears in the morning sky after its June 7 inferior conjunction with the Sun. Look for it popping out of the morning twilight during the month's last few days.

On June 28, 0.7-magnitude Mercury rivals Aldebaran, which shines at magnitude 0.8. Mercury lies 7° to the lower left of Aldebaran, low in the brightening eastern sky. Begin watching an hour before sunrise. A waning crescent Moon stands watch above the pair. Mercury brightens to magnitude 0.6 by the next morning, when the Moon has moved east of the Pleiades (M45) and lies 12° above Aldebaran. The planet's visibility improves in early July.

This is the month when the **Sun** reaches its northernmost declination along the ecliptic, which means nighttime hours reach their minimum span. The event, called the summer solstice, occurs June 20 at 7:59 P.M. Eastern Daylight Time.

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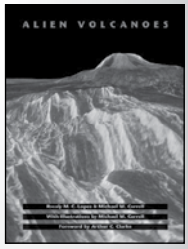

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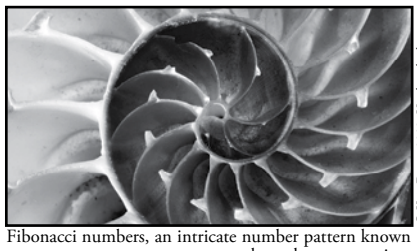

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Fibonacci numbers, an intricate number pattern known as a recurrence sequence, appear throughout nature in unexpected places like the spirals of shells.

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Edward B. Burger, Professor of Mathematics in the Department of Mathematics and Statistics at Williams College, earned his Ph.D. from The University of Texas at Austin. Professor Burger's teaching and scholarly works have been nationally recognized; most recently, Williams College awarded Professor Burger the 2007 Nelson Bushnell Prize for Scholarship and Teaching.

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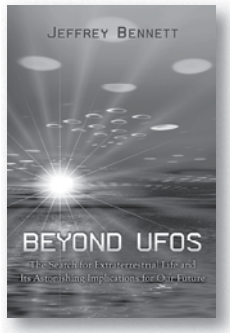

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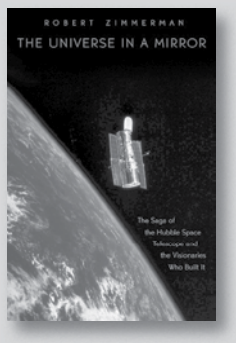

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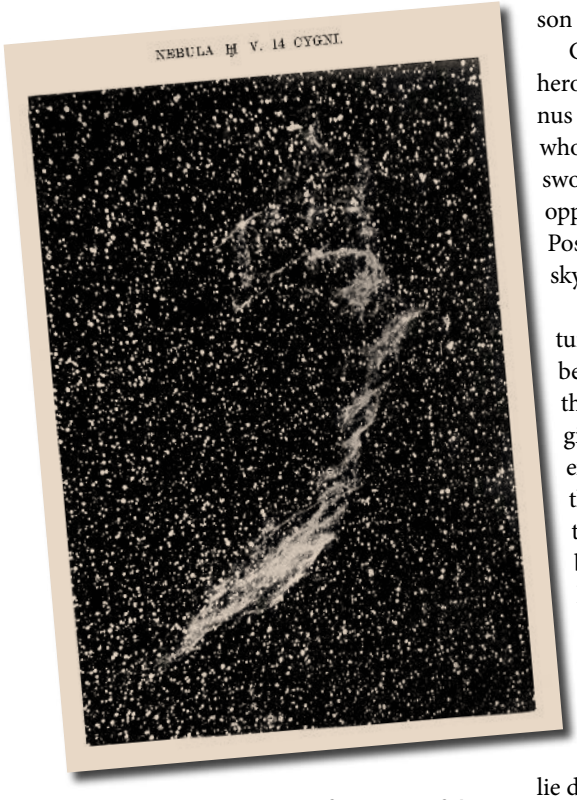
When you observe this expanding ring of light, you'll trace the ghostly remnant of an ancient supernova. /// **BY RAYMOND SHUBINSKI**

All about the Veil Nebula

The Veil Nebula rides high in the northern summer sky on the wings of the beautiful constellation Cygnus the Swan. Cygnus' brightest star, Deneb, along with Altair in Aquila and Vega in Lyra, form the well-known asterism of the Summer Triangle, which encloses a fabulous portion of the Milky Way. Within Cygnus lie numerous binocular and telescopic objects that delight observers. The Veil Nebula ranks as one of the most fascinating — and challenging.



THE EARLIEST IMAGE of any part of the Veil Nebula is this one of NGC 6992, captured by English astrophotographer Isaac Roberts (1829–1904) and printed in his *Selection of Photographs of Stars, Star Clusters and Nebulae*, Vol. 2, 1899. COURTESY LINDA HALL LIBRARY OF SCIENCE, ENGINEERING, AND TECHNOLOGY

Myths galore

During the reign of emperor Caesar Augustus, Roman poet Ovid (43 B.C.–17 A.D.) wrote the *Metamorphoses*. Its stories deal with death and transformation. One of the tales highlights the Trojan warrior Cygnus, son of the sea-god Poseidon.

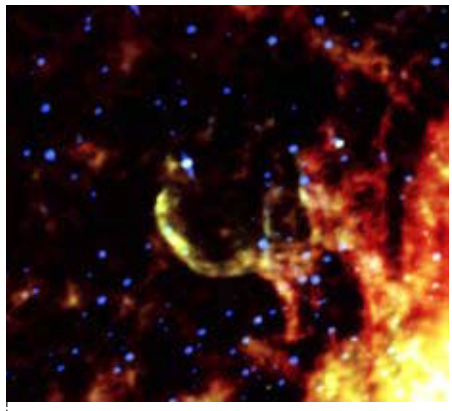
Cygnus boldly challenged the Greek hero Achilles to combat. As bravely as Cygnus fought, he was no match for Achilles, who pummeled Cygnus with a shield and sword. When Achilles went to claim his opponent's armor, the body was gone. Poseidon had transported Cygnus into the sky on the back of a magnificent swan.

Another Greek myth relates how Zeus turned himself into a swan to seduce the beautiful nymph Nemesis. The result of this union was a single egg, which was given to Leda, Queen of Sparta. The exquisite Helen (whose birth resulted in the destruction of Troy) hatched from the egg. Zeus placed the swan he became into the sky in remembrance of his amorous adventure.

Other stories say the swan is the musician Orpheus, who the gods transformed into a bird and placed near the beloved harp he invented, Lyra. But even more transformations lie deep within the Veil Nebula that today are the territory of astronomers.

Discovery and history

English astronomer Sir William Herschel (1738–1822) first spotted the Veil Nebula September 5, 1784. In 1783, Herschel began



THE VEIL NEBULA'S CLOUDS give off lots of heat. This Infrared Astronomical Satellite (IRAS) image shows infrared emission from dust grains in the supernova remnant's expanding shell.

Astronomers color-coded the image to display relatively warm infrared emission as blue, cooler emission as green, and the coldest emission as red. The blue dots are stars, and the diffuse emission to the right of the Loop is from interstellar dust grains heated by starlight. NASA

what he called "a series of observations (or Sweeps of the heavens), which I am still continuing till the whole be completed."

Like all astronomers since the invention of the telescope, Herschel needed as much light-gathering power as he could muster. At the time he was using a homemade telescope. It had a 20-foot (6.1 meters) focal length and a speculum (an alloy of 70-percent copper and 30-percent tin) mirror almost 19 inches (0.5m) in diameter.

Even with this large telescope, Herschel was looking for ways to gather more light. In a note from his first catalog of deep-sky objects, *Catalogue of One Thousand New Nebulae and Clusters of Stars*, he describes how he developed what current observers call the "Herschel focus."

He says he used the "front-view" observation method. This "consists in looking

THE VEIL NEBULA is a supernova remnant within the constellation Cygnus the Swan. The star whose outer atmosphere created the Veil Nebula exploded some 5,000 years ago. The Veil measures 3.5° by 2.3°, making it one of the sky's largest celestial objects. ADAM BLOCK/NOAO/AURA/NSF

IF YOU THINK the Moon's big, this image shows it to the scale of the Veil Nebula image at left. LICK OBSERVATORY

with the eye glass, placed a little out of the axis, directly in at the front, without the interposition of a small speculum [a diagonal mirror]; and has the capital advantage of giving us almost double the light of the former constructions."

In 1784, Herschel was using every trick he could think of to capture more light. In his original catalog, he gave the Veil three number designations, and there have been many names associated with the object since Herschel's discovery. Even the name "Veil Nebula" is a product of the 1930s.

Raymond Shubinski *is director of the Atomic Testing Museum in Las Vegas, an astronomy historian, and a dedicated deep-sky observer.*

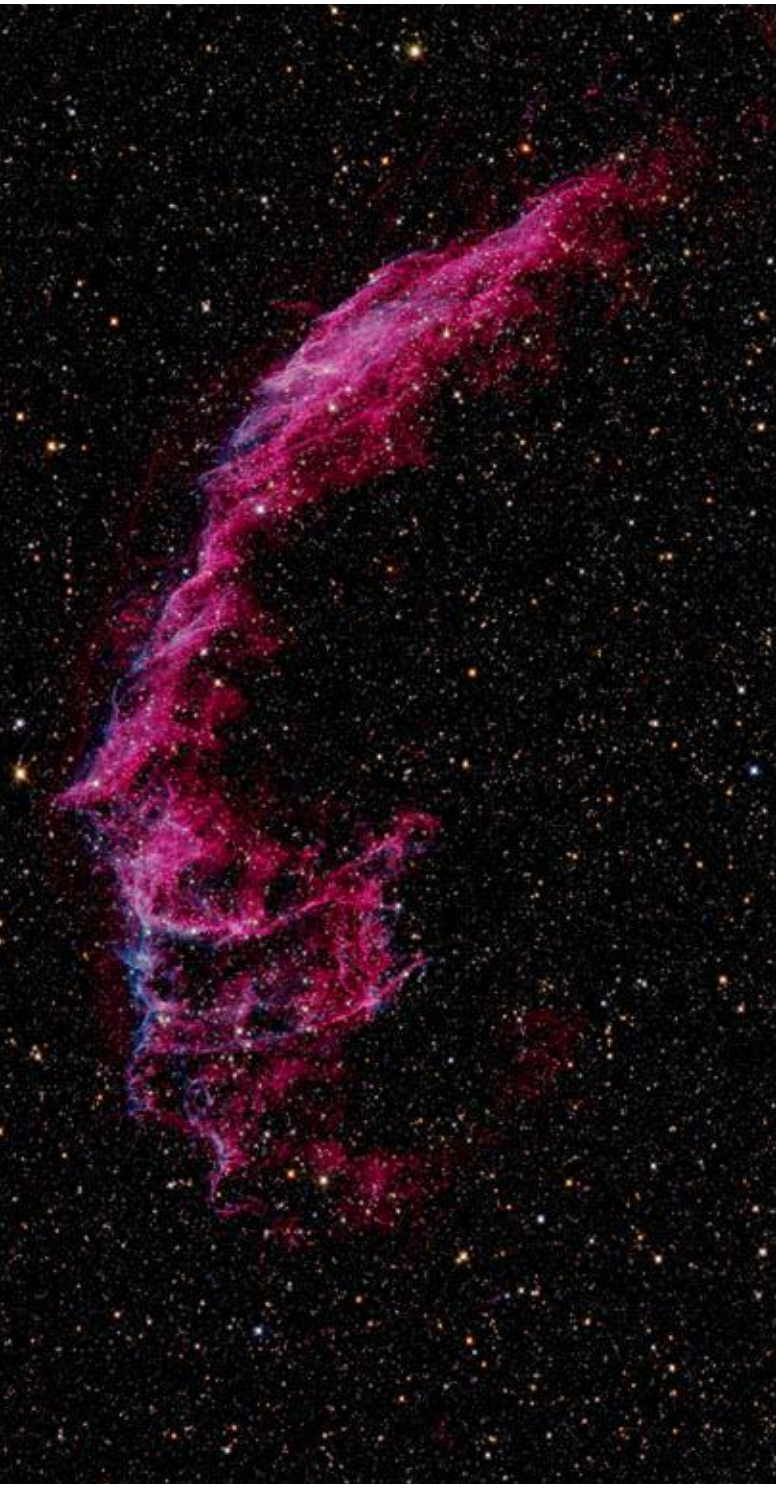
The physics behind the Veil

Astronomers classify the Veil as a supernova remnant, but its ethereal tendrils glow like an emission nebula. We see emission nebulae because their atoms absorb ultraviolet light from hot stars and then reradiate that energy as light. However, no such star is close enough to the Veil to cause this effect. The reason it glows lies in the nature of the star that created the nebula. Sometime between 5,000 and 10,000 years ago, a massive nearby star self-destructed in a gigantic explosion called a supernova.

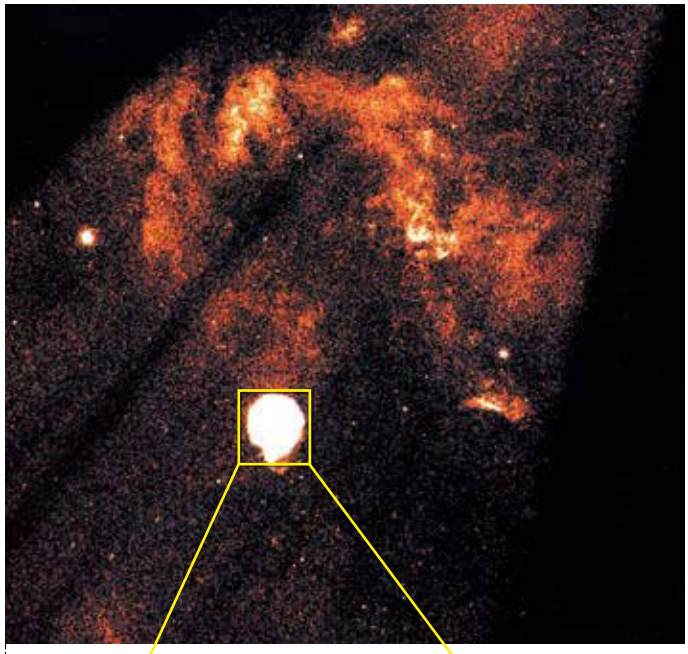
How a star lives and dies depends on only one factor — its mass. Our Sun is a relatively modest star that uses its nuclear fuel slowly compared with stars with more gas and, thus, mass. Stars like our Sun convert hydrogen into helium for nearly 10 billion years. The star that formed the Veil Nebula may have been as much as 40 times as massive. Like a high-powered sports car, it used its fuel at an incredible rate, so it lasted only a few million years.

During this time, the star would have shrunk and expanded many times. As it underwent this process, the star would have ejected shells of matter into space like an onion peeling its own layers. Finally, the star's core collapsed and rebounded in a massive explosion.

Material from the star would have been flung into space at speeds approaching 1 million mph (1.6 million km/h). From



THE NETWORK NEBULA (NGC 6992) marks the eastern edge of the Veil Nebula complex. NGC 6992 is the long extension that stretches to the top (north) in this image. The dense, wide portion to the bottom is NGC 6995. THOMAS V. DAVIS



THE CYGNUS SUPERBUBBLE is a highly structured, hot gas shell. The ESA's X-ray satellite ROSAT surveyed the entire 13°-wide object at high resolution in 1992. A molecular cloud in the foreground shades the lower right part. The overexposed white patch slightly below center is the Cygnus Loop, a much closer supernova remnant.

The 2-million-degree Cygnus Superbubble lies about 6,000 light-years away and measures 1,500 light-years across. It formed by the interaction of the strong stellar winds and supernova explosions of a young star cluster. MAX-PLANCK INSTITUTE FOR EXTRATERRESTRIAL PHYSICS

THIS CLOSE-UP X-RAY IMAGE of the Cygnus Loop obtained during the ROSAT All-Sky Survey shows the cloud's many bright, filamentary structures. This supernova remnant has preserved its spherical shape except for a break-out toward the south. This image lets astronomers study the temperature and density of the structure at high resolution (a few arcminutes). MAX-PLANCK INSTITUTE FOR EXTRATERRESTRIAL PHYSICS

Earth, any ancient skywatcher would have seen the supernova glowing almost as brightly as the Full Moon. In our sky today, the stars Antares (Alpha [α] Scorpii) and Betelgeuse (Alpha Orionis) are similar to the star that created the Veil Nebula.

As gas ejected by the supernova explosion moved outward in a bubble, it encountered the gas remnants previously shed by the star. This created a shock-front, causing the emissions we now see. The main elements in this gas near the shock-front are oxygen, sulfur, and hydrogen. Astronomers haven't identified a neutron star or black hole as part of the structure. Such stellar corpses are the normal by-products of supernova explosions.

It's difficult to determine the distance to an object such as the Veil Nebula. Recent studies made using the Hubble Space Telescope indicate the Veil Nebula may lie as close as 1,470 light-years. In 2003, researchers using the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite measured the distance of a star behind the Veil Nebula at 1,860 light-years, giving an outside boundary for the Veil's distance.

Today's challenge

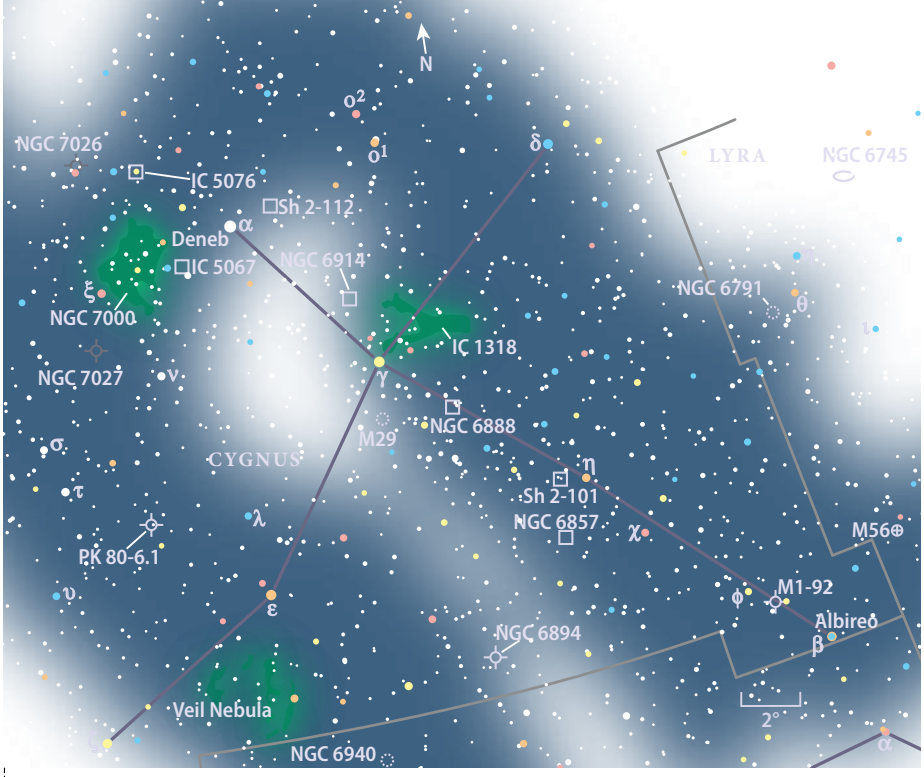
Early observers such as Herschel saw a number of nebulous objects in the Veil's 3°-wide area, which is equal to 6 Full Moons side by side. It's no wonder they didn't realize these nebulae were all part of the same catastrophic event.

The Veil Nebula's overall surface brightness equals a 5th-magnitude star. Under the darkest skies, some observers claim to have seen the nebula without optical aid. This seems doubtful, but it would be interesting to hear reports from avid skywatchers.

Unlike Herschel and his contemporaries, modern amateur astronomers have a vast arsenal of equipment for making their "sweeps of the heavens." Today, you can choose from large-aperture stabilized binoculars, high-quality short-focal-length refractors, and monster reflectors. This technological array makes the Veil Nebula a fairly easy target. The only challenge is choosing an observing site away from city lights, because any light pollution will wash out your view.

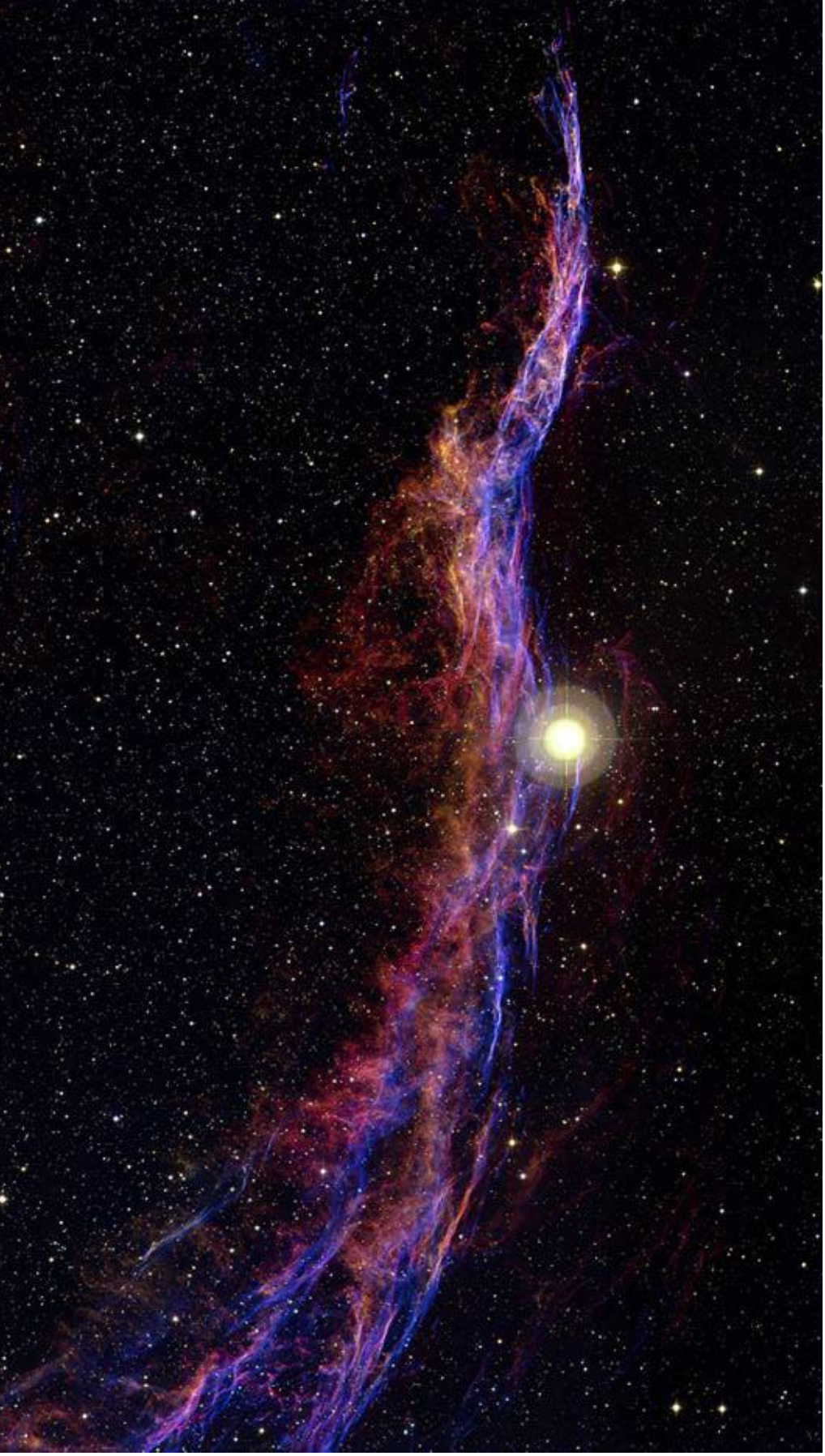
Finding the Veil

Summer is when the Swan flies along the star-encrusted Milky Way. On a moonless night far from city lights, this portion of the



USE THIS FINDER CHART to locate the Veil Nebula (NGC 6960 and NGC 6992/5). This supernova remnant sits within a right triangle formed by the stars Epsilon (ε), Zeta (ζ), and 52 Cygni. The Veil Nebula stretches across more than 3° of sky, so use low power. The magnitude 4 star 52 Cygni lies in front of NGC 6960. *ASTRONOMY:* RICHARD TALCOTT AND ROEN KELLY

A SMALL PART of the Veil Nebula shows astronomers how supernova shock-fronts move through space. In this false-color Hubble Space Telescope image, the blast wave, which is moving from left to right, has recently hit a cloud of denser-than-average interstellar gas. The collision drives the shock wave into the cloud, heating the gas and causing it to glow. JEFF HESTER (ARIZONA STATE UNIVERSITY)/NASA



THE WITCH'S BROOM (NGC 6960) forms the western section of the Veil Nebula. Astronomers combined data through Hydrogen-alpha, Oxygen III, and Sulfur II filters and assigned red, blue, and green colors, respectively, to create this image. The magnitude 4.2 star, 52 Cygni, lies less than 200 light-years away — one-seventh the Veil Nebula's distance — so it isn't part of the nebula. T. A. RECTOR/UNIVERSIY OF ALASKA ANCHORAGE/WIYN/NOAO/AURA/NSF

/// VEIL NEBULA STATISTICS

Also known as: NGC 6960/74/79/92/95, Caldwell 33 (NGC 6992/5), and Caldwell 34 (NGC 6990)
Other common names: the Bridal Veil Nebula, the Cygnus Loop, the Filamentary Nebula, Fleming's Triangular Wisp, the Network Nebula, Pickering's Triangle, the Tornado Nebula, the Witch's Broom Nebula
Right ascension: 20h56m
Declination: 31°43'
Magnitude: —
Apparent size: 210' by 160'
Distance: 1,400 light-years
Best seen: Northern Hemisphere summer
Visible: north of latitude –58°

sky takes on a magical quality. Deneb (Alpha Cygni) marks the Swan's tail. The body is the star Sadr (Gamma [γ] Cygni). The long neck terminates with the star Albireo (Beta [β] Cygni). The wings extend out from Sadr to Delta (δ) Cygni on the bird's northwest side and to Epsilon (ε) Cygni on the southeast side.

Once you find Epsilon, move south about 3° and look for the 4th-magnitude star 52 Cygni. Through a 6-inch or larger telescope, you'll see a faint smudge of light around 52 Cygni. This is NGC 6960.

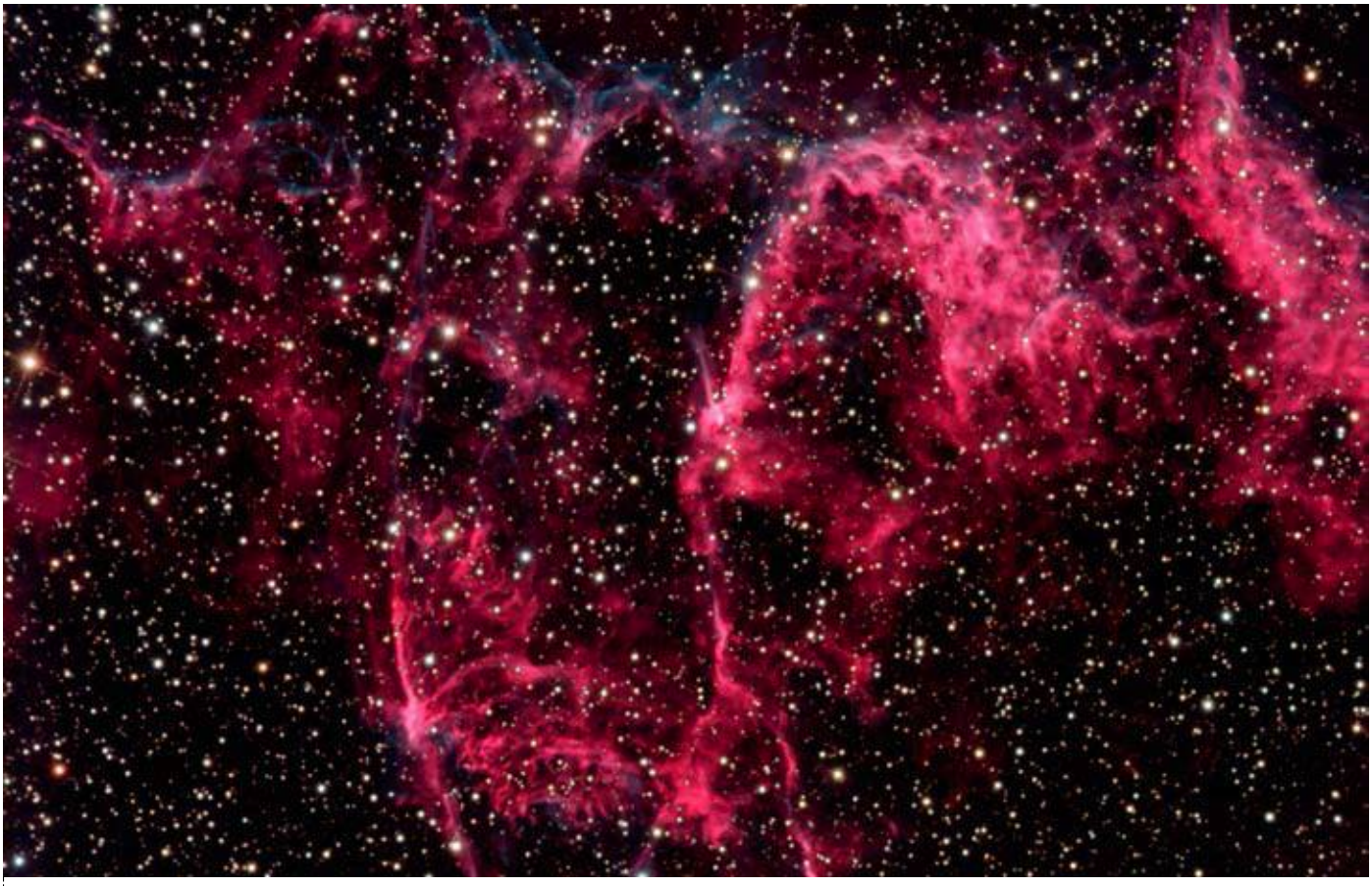
As you sweep the area, you should find at least one other extended smudge, although not as prominent as NGC 6960. Viewing these objects is easier through an OIII filter because such a device allows the light from the Veil's glowing gas through, but blocks most other wavelengths.

What's in a name?

If you think the mythology of Cygnus is complicated, so is the nomenclature of this gossamer object. The Veil Nebula has five NGC numbers assigned to it, and each seems to have several names.

Observers call NGC 6960 the Filamentary Nebula, the Cirrus Nebula, and the Tornado Nebula. It's best known as the Witch's Broom, perhaps because of the way its structure expands southward. Through a telescope, it's easy to see that, north of 52 Cygni, the nebula narrows almost to a point. South of 52, the nebula spreads out, creating the appearance of a broom.

Herschel gave the eastern portion of the nebula opposite the Witch's Broom a bit more description. He saw this part of the



THE LACEWORK NEBULA (NGC 6995), called the Bridal Veil Nebula by American astronomer Robert Burnham, Jr. (1931–1993), connects directly to another of the Veil's parts, NGC 6992. Assigning magnitudes to extended objects like the Lacework Nebula is difficult, but astronomers estimate NGC 6995's total light output equals that of a 7th-magnitude star. BOB AND JANICE FERA

Veil — now referred to as NGC 6992/6995 — as "Branching nebulosity, extending in RA near 1½ degrees and in DEC. 52'. The south part divides into several streams uniting again towards the south."

Amateur astronomers refer to this part of the Veil Nebula as the Network Nebula because of the complex structure visible through a large-aperture telescope. In *Burnham's Celestial Handbook*, American astronomer Robert Burnham, Jr., (1931–1993) referred to this section of nebulosity as the Bridal Veil Nebula.

A veiled honor

In the late 19th century, astronomers became overwhelmed by raw data. Improvements in photography and spectroscopy had provided mountains of information that had to be processed and analyzed. In the 1880s, one of the most active centers of research was at Harvard Observatory in Cambridge, Massachusetts.

The director, Edward C. Pickering (1846–1919), was an irascible fellow. With his well-cropped beard and immaculate suits, employees throughout the observatory revered and feared him.

At this time, the only "computers" available to reduce data were armies of students, mostly male. At one point, Pickering was so frustrated with computing quality that he said his housemaid could do a better job. To prove his point, he hired his 23-year-old maid, Williamina Fleming (1857–1911), to take over some of the work.

Fleming was a recent immigrant from Scotland. She had come to the United States when she was 21. By age 22, she'd had a child and her husband had abandoned her. Fortunately, she found work in Pickering's household. Fleming was a fast learner who developed a stellar classification system. She found herself supervising new "computers," all of whom were young women.

Fleming also spent time reviewing hundreds of photographs. While inspecting a plate of the Veil Nebula, she noticed a wedge-shaped nebula near the north end of NGC 6960. She named this nebula — NGC 6979 — in honor of Pickering, and it's now often referred to as Pickering's Triangle. Some observers choose to honor Fleming, however, so NGC 6979 also has the name Fleming's Triangular Wisp.

Fleming went on to discover more than 50 nebulae, 10 novae, and hundreds of variable stars. The Royal Astronomical Society even made her an honorary member. Pickering was right; his maid could do better.

With the fabulous images of the Veil Nebula now available from the Hubble Space Telescope, the naming could go on and on. The twisted tendrils of gas give endless opportunity to the imagination and an ongoing challenge to observers with all types of equipment.

Imagine yourself standing next to William Herschel as he swept the heavens, finding new and beautiful objects. Herschel could only speculate at the nature of what he saw. Today, we simply pick up an astronomy book to find the details.

A book, however, will never replace the enjoyment of finding this supernova remnant for yourself under a dark sky. Whatever you call the Veil Nebula, like Herschel, observers still gaze at it with wonder.

Head north to increase your odds of glimpsing colorful aurorae

OBSERVING AURORAE

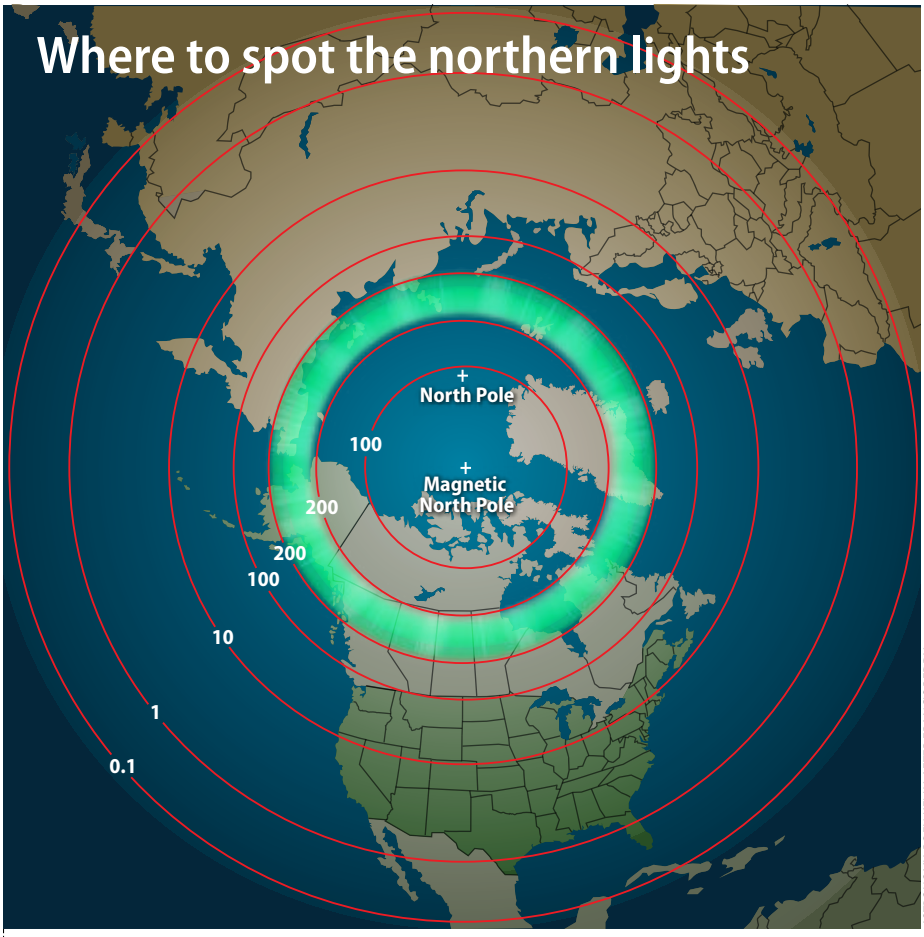
Q: Where's the best place to view aurorae?

— **JOHN APPEL,** APOPKA, FLORIDA

A: Your best chance of catching aurorae occurs in regions where the auroral oval is overhead most often. The oval forms where electrons and other particles intercept the atmosphere as Earth's magnetic field channels them toward the poles. Intense solar storms have the effect of expanding the oval toward the equator. In fact, on average, you could see aurorae from central and southern Florida about one night every few years, assuming you knew just when to look.

The odds get better the farther north you go, but only up to a point. **Aurorae occur about 200 nights a year along a band running from central Alaska through the northern halves of British Columbia, Saskatchewan, Manitoba, Ontario, and Quebec.** Farther north, aurorae frequencies actually decrease.

— **FRANCIS REDDY,** SENIOR EDITOR



ASTRONOMY: ROEN KELLY, AFTER FRANCIS REDDY

AURORAL DISPLAYS OCCUR MOST FREQUENTLY in a narrow band (green) centered on Earth's magnetic north pole. In this region, the colorful northern lights dance in the sky about 200 nights a year. Numbers reflect how many nights a year aurorae are typically seen.

POINT SOURCES

Q: Have we ever seen any star as more than a point of light? — **RON WILSON,** AMHERST, NEW YORK

A: Yes. In 1995, astronomers using the Hubble Space Telescope's Faint Object Camera imaged the disk of Betelgeuse, the brightest star in Orion. Betelgeuse, a red supergiant, is about 600 times the Sun's diameter and lies relatively nearby, just 425 light-years away. This combination gives Betelgeuse the largest apparent diameter of any star beyond the Sun.

At optical wavelengths, Betelgeuse's disk is about 0.055" across. In the ultraviolet, though, the star's extended UV-emitting chromosphere makes it 2.2 times bigger. This enabled Andrea Dupree of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and Ronald Gilliland of the Space Telescope Science Institute in Baltimore, Maryland, to image Betelgeuse's disk. They compare the feat to resolving a car's headlights from about 6,000 miles (9,700 kilometers) away.

The Hubble images revealed an enormous bright spot, more than 10 times Earth's diameter, that is at least 3,100° F (1,727° C) hotter than the rest of the star's surface. Astronomers think the bright spot may be related to the star's magnetic activity. — **FRANCIS REDDY,** SENIOR EDITOR

VISIBLE UNIVERSE

Q: Because the universe was smaller at earlier times, do we see larger volumes of it as we look back in time? — **RONALD HELLMAN,** KERHONKSON, NEW YORK

A: Yes. If we observe a galaxy 5 billion light-years away, we see it at a time when things were much closer together. Then, that galaxy and its neighbors occupied a space about one-eighth the volume they do today. To put it another way, an alien 5 billion light-years distant would see the Milky Way and Andromeda galaxies separated by only half the distance they are today.

Looking backward in time at progressively distant objects is a bit like seeing an old picture. The farthest back we can see in electromagnetic waves — light — is the cosmic microwave background (CMB) radiation. That's so long ago that two features separated by an amount equal to the Sun-Alpha Centauri distance, about 4 light-years, now span about 10 percent of the Milky Way. Of course, those two features have changed a great deal in the intervening billions of years.

— **SIMON DEDEO,** KAVLI INSTITUTE FOR COSMOLOGICAL PHYSICS, UNIVERSITY OF CHICAGO

CELESTIAL COORDINATES

Q: How do right ascension and declination relate to longitude and latitude?

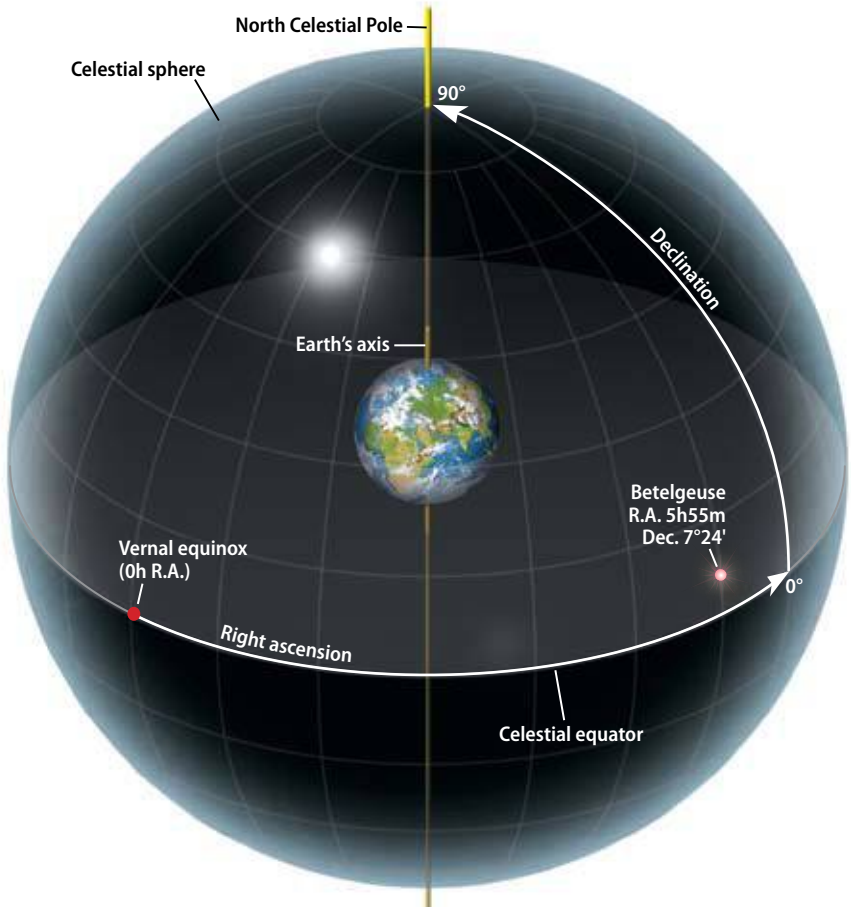
— **GEORGE STOCKWELL,** SANDY HOOK, CONNECTICUT

A: Right ascension and declination form a celestial coordinate system. Astronomers modeled it after the terrestrial coordinate system of longitude and latitude. **Declination is measured in degrees and resembles latitude. Objects lie either above or below the celestial equator, just like locations on Earth.**

Right ascension is measured in hours and resembles earthly longitude, except for one major difference: As Earth rotates, the right ascension overhead appears to change. But because astronomers anchored the coordinate to the sky, a celestial object's right ascension doesn't change; at least, not during the course of a human's lifetime.

Your longitude, therefore, has nothing to do with right ascension. The longitude coordinate of any terrestrial location remains the same as Earth rotates. The right ascension coordinate of any celestial object remains the same as the sky appears to rotate. — **MICHAEL E. BAKICH,** SENIOR EDITOR

Understanding celestial coordinates



RIGHT ASCENSION and declination define a celestial object's coordinates. The so-called equatorial coordinate system is based on the celestial sphere, a voluminous, imaginary sphere centered on Earth. *ASTRONOMY:* ROEN KELLY

COMING NEXT MONTH...
Could nearby stars Alpha Centauri A and Alpha Centauri B have terrestrial planets orbiting them in stable, circular orbits?

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

WEB EXTRA
- Listen to a podcast about how to measure a star's distance at www.Astronomy.com/toc.
- Post your Ask Astro comments online at www.Astronomy.com/forums.

IN THE KNOW

AURORAL OVAL
Regions on Earth where aurorae, also called the northern and southern lights, occur most often and most intensely.

RIGHT ASCENSION
The angular distance of a celestial object east of the vernal equinox; the celestial sphere equivalent of longitude.

DECLINATION
The angular distance of a celestial object above or below the celestial equator; the celestial sphere equivalent of latitude.

Use the Clear Sky Chart to turn specialty weather maps into custom astronomy forecasts. /// BY FRANCIS REDDY

Will you see the stars tonight?

Assembling a quality weather forecast

for your observing site could be a trying task. An ideal site forecast should include the usual information — temperature, cloudiness, and humidity — as well as additional atmospheric properties of interest to astronomers.

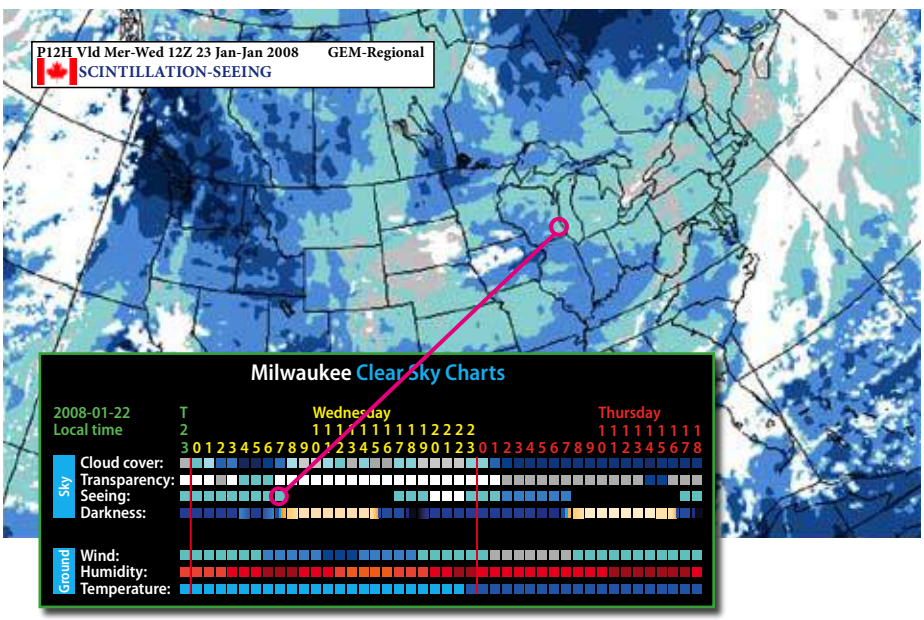
Attilla Danko, a professional computer programmer for QNX Software Systems in Kanta, Ontario, knows just how hard locating this information can be. He's an avid amateur astronomer and confesses he spent a long time searching the Internet for weather forecasts directed at astronomers.

In 2001, he stumbled onto an obscure web page titled "Weather forecasts for astronomy" (www.weatheroffice.gc.ca/astro/index_e.html) created by the Canadian Meteorological Center (CMC) in Dorval, Quebec. The CMC produces detailed digital maps that predict astronomically relevant conditions for the United States and Canada up to 48 hours in advance.

That's the ticket, Danko thought. "But I found myself downloading hundreds of maps of all of North America just to see if I could observe in my backyard." What he calls his "moment of laziness" came when he realized he didn't need the entire map, just the pixel corresponding to his observing location. "So I wrote a script to automatically download several hundred maps and strip out the pixel for my backyard."

He enlarged the pixels and arranged them chronologically in a row. At a glance, Danko now could see forecast weather conditions for both heaven and Earth: temperature, humidity, and cloud cover, plus two astronomically important factors known as seeing and transparency.

The Clear Sky Chart was born. "My mistake was telling a friend," he jokes, because word got around fast. Now, with the help of four computers, two web hosts, and a pair of DSL lines, Danko's web site (www.cleardarksky.com/csk) produces the same custom graphic for more than 3,200 North America locations. "Sponsors reduce some of the costs of Internet access, web hosting, computers, software development, and caffeine that I use to generate Clear Sky Charts," he says. "My little script has grown to 53,000 lines in a dense programming language."



SEEING CONDITIONS BECOME BLUE AND GRAY BLOTCHES in this map produced by the Canadian Meteorological Center. White regions indicate cloud cover. Areas with the best seeing conditions appear deep blue. *Inset*: The Milwaukee Clear Sky Chart shows how conditions at the map pixel matching Milwaukee's location change over time. CMC AND ATTILLA DANKO

Seeing the light

Both seeing and transparency affect the quality of telescopic images. "Seeing" is the term astronomers use to quantify the atmosphere's steadiness. The more turbulent the air is, the more it blurs fine image details. Until adaptive optics systems make their way into amateur scopes, seeing conditions will limit a telescope's resolving power.

All moving air — such as tube currents in your scope and warm air rising from buildings — creates turbulence, and turbulence creates shaky images. On a night of especially bad seeing, Jupiter's disk might show only the planet's two main cloud bands. The image in the eyepiece falls apart at magnifications above 150x. On a good night, observers can push a telescope to its limits — 50x per inch of aperture for a

Francis Reddy *is a senior editor of* Astronomy.

quality scope — to reveal Jupiter's many white spots and cloud bands.

The single most important weather factor correlated with good seeing is light wind at the surface, says CMC meteorologist and amateur astronomer Allan Rahill, who produces the center's astronomy forecasts. His 1990 study showed that winds between the surface and 3,000 feet (900 meters) primarily determine seeing conditions.

In a 2005 study of 23 professional observatories, René Racine at the University of Montréal found that air within the first few hundred feet dictated seeing conditions at the observatories' altitudes. "This indicates surface winds and heat radiating from the ground have a major impact on the final image," Rahill explains.

You'll find the best seeing near the center of high-pressure systems, which have weak surface and upper-level winds. Rahill notes that the steadying effects of high, thin cirrostratus clouds promote excellent planetary viewing.

Seeing improves at the top of a hill because air cooling near the hilltop flows smoothly downslope. Rahill also notes that seeing is "a notch or two better" 30 to 60 minutes after sunset and before sunrise. It's also slightly better an hour ahead of the cirrus and altostratus clouds from an advancing storm system.

Rahill says that the harbinger for a spell of good observing is an "omega block" weather pattern. This is a combination of two low-pressure systems and one high-pressure zone that resembles the capital Greek letter omega (Ω).

The lows, which form the legs, lock a high-pressure bubble between them. When the eastern low stalls or moves slowly, it blocks the other systems. That's bad news if you're under the stormy lows, but it's great for observers under the high.

In the clear

Transparency is the other atmospheric quality important to astronomical observing. The cleaner and more cloud-free the air, the better skywatchers can see faint deep-sky objects like galaxies and nebulae. Astronomers evaluate transparency by noting the faintest star visible to the unaided eye.

In arid regions of the American Southwest, such as Arizona, observers may see stars fainter than magnitude 6.5. In the more humid eastern parts of the country, this may fall to magnitude 5.5 at a dark country site. "Smoke from forest fires and windblown dust can ruin transparency, too," Danko says.

The CMC's transparency predictions derive from satellite information on the atmosphere's total water content. Transparency varies with the type of air mass. Humid summer air is less transparent than that of a crisp winter's night. However, other elements that affect transparency — like smog, smoke, or dust — aren't included in the CMC forecast.

The sky is especially clear in the wake of a strong cold front. "A strong and fast-moving cold front, followed by strong northwesterly winds, will produce the deepest sky we can experience in North America," Rahill says. The reason: Strong downward airflow (subsidence) behind the front dries and stabilizes the air mass and sweeps away airborne particles.

"Locations with permanent dry weather, such as over the southwestern U.S., get the best transparencies for astronomy, but not the best seeing," Rahill notes. Local meteorological effects — especially waves generated by frontal systems or by air flowing over mountains — stir the atmosphere.

Chart your sky

Armed with a little knowledge about what affects seeing and transparency, you may look a little differently at the nightly TV weather forecast. But you can go one better.

Visit Attilla Danko's web site. If there's a Clear Sky Chart for your favorite observing locale, it may give you the best portrait of your astronomical observing opportunities you've ever had. And if there isn't, be sure to tell Attilla. He'll take requests for places more than 15 miles (24 kilometers) from those he's already charting.

ON NEWSSTANDS JUNE 17
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Capturing beautiful sky panoramas is easy if you follow these simple steps. /// **TEXT AND IMAGES BY IMELDA B. JOSON**

Master the art of wide-field imaging

THIS ASTROPHOTOGRAPHY SETUP comprises a ball-head-mounted Canon EOS 20D digital SLR camera with a 28mm to 135mm zoom lens, an electronic cable release (bottom), a bubble level on the camera flash's hot shoe, and a right-angle 2.5x magnifier for the viewfinder.

The Sun sets on a cool, clear spring evening. Its light bathes the western sky in a rich palette of yellows, pinks, and reds. As twilight fades, a pair of celestial beacons catches your eye high above the treetops. One is the thin crescent Moon with its dark side delicately illuminated by earthshine. Hanging next to the Moon is Venus, dazzling in all its resplendent glory.

Many of us have seen such a stunning scene before. It's something we'd want to capture in a photograph to hang in our homes or offices, share with family or friends, or post on the web. And it's a souvenir shot that virtually anyone can take using equipment already on-hand. Whether you're shooting wide-field portraits of conjunctions (close groupings of celestial objects), eclipses, or star trails, use these tips to capture the sky's natural beauty.

Your basic gear

The typical setup for wide-field imaging is a camera and a tripod. Practically any film or digital camera can capture sky scenes. The key requirement is the camera's ability to take time exposures.

Digital cameras offer the advantage of letting you instantly preview your images. You can see exactly how the image looks on the camera's built-in LCD screen. This makes it easy to check your focus and exposure settings so you can correct them on the spot if needed. Is the image overexposed? Out of focus? Simply delete the image and try again.

Ideally, your tripod should be sturdy and solid but light enough for easy transport to remote locations. For better stability, it should also be able to bring the camera close to eye level by extending its legs and without having to raise its center column. A quick and easy way to aim the camera and frame your photo is to use a compact ball-head mount on your tripod.

But before you head out into the field, you should know about the importance of good composition.

The rule of thirds

Composing your sky shot means presenting the picture's visual elements — your main

VENUS AND SATURN shine next to the Minute Man monument in Concord, Massachusetts, at dusk June 30, 2007. The author used the "rule of thirds" to compose this shot. The bright star Regulus lies left of the statue.

A TOURIST ATTRACTION in Rockport Harbor, Massachusetts, served as a picturesque foreground to this digital sequence. Here, the Full Moon rises and progresses through the final stages of the March 14, 2006, penumbral eclipse.

A FULL MOON RISES over Boston's skyline. On June 21, 2005, the author used a digital camera on a tripod to snap the series of lunar images in this composite. The camera can't record multiple exposures on a single frame, so the author took separate exposures and digitally combined them.

subject and foreground — in an aesthetically pleasing way. Good composition is simple, balanced, and harmonious. Merely pointing your camera at a scene doesn't always work. Proper framing is essential because it can make the difference between a nice shot and a great photo.

Use a technique landscape photographers refer to as the "rule of thirds" to position your subject in the frame. Imagine your camera's field of view divided into thirds both vertically and horizontally. This creates a tic-tac-toe pattern. Place your subject near one of the four points where the imaginary lines intersect to enhance your composition's visual appeal.

For example, the horizon usually looks more dynamic when placed in the bottom third of the picture rather than having it run across the middle of the frame. Also, avoid positioning your subject dead center in the view; oftentimes, the result looks static and not visually compelling.

Plan your imaging session

Keep a calendar of upcoming sky events for photo opportunities. Desktop-planetarium software can help you plan your shot. Or you can use *Astronomy* magazine's "Sky This Month" section or the StarDome Plus feature on our web site (Astronomy.com/asy/stardome) to get the rise, set, and transit times, and altitude and azimuth for the Sun, the Moon, and other celestial objects, as well as twilight data, Moon phases, and solar and lunar eclipses. The U.S. Naval Observatory's Almanac web site (aa.usno.navy.mil/data/) is another great resource for astronomical information.

If you live in the city or suburbs, you probably appreciate the negative effects of light pollution. This unnatural sky glow washes out detail and contrast in celestial objects and severely limits how long of an exposure you can take. So if you want to shoot star trails or the Milky Way, you need to find a site away from city lights.

Arrive at your site before dark and walk around to visualize the best composition for your foreground and sky subject. Even a few steps forward, backward, or sideways can make a difference. Once you've selected a good vantage point, hold the camera with your hands at eye level and look through the viewfinder. Which works better — a horizontal or vertical composition? This is a matter of personal choice; if you're not sure, shoot both.

After mounting the camera on the tripod, make any final adjustments to your composition. If you're using a zoom lens, try switching from a wide-angle view to a close-up one to crop out any unwanted

ALWAYS HAVE YOUR CAMERA gear ready for unexpected photo opportunities. The author captured this spectacular display of the aurora borealis, or northern lights, from her driveway in suburban Boston November 10, 2004.

ARMED WITH A TOPOGRAPHIC MAP and lunar altitude/azimuth data, the author nicely framed the Moon's conjunction with Venus and dim Saturn July 16, 2007. The Annisquam Lighthouse in Gloucester, Massachusetts, lies in the foreground.

portions of the scene. And before you open the shutter, be sure to check the viewfinder for any distracting objects, such as glare from a distant porch light or a low-flying plane that's about to cross the frame.

You can add an artistic touch to a twilight conjunction scene by including interesting foreground silhouettes. For example, in the desert you can add a saguaro cactus or rock formation next to the Moon and planets; in the city, you can include a church steeple, a monument, or a bridge. You can also add people observing in the foreground. All these create a scene's sense of place and scale. Seek unusual perspectives, and don't be afraid to experiment.

For example, if you plan to shoot a lunar-eclipse sequence, be sure to test your equipment and practice your procedure several nights before the actual event. This will give you an idea of where the Moon will rise and set and how it will move across your sky. You may also decide how best to frame the sequence with respect to trees, buildings, or other familiar landmarks.

Exposure times will vary depending on your subject. If you want to capture stars as points of light, you'll have to keep your exposures brief. With short-focal-length lenses, exposure times can last up to about a minute on a fixed tripod without the stars "trailing." Longer exposures or focal lengths require a motor-driven, polar-aligned equatorial mount to track celestial objects accurately and prevent images from smearing. To record star trails, aim the camera at a fixed spot in the sky and lock the shutter open for a few hours. Earth's rotation will

Imelda B. Joson *is the former photo editor of* Sky & Telescope *magazine. She and her husband, Edwin L. Aguirre, have been shooting the sky for nearly 30 years.*

IF YOUR CAMERA HAS SPOT-METERING capability, take a reading of the twilight sky. You'll record the foreground as silhouette. The author shot Venus, Saturn, and Regulus (upper-left of pair) setting over Horn Pond in Woburn, Massachusetts, June 29, 2007.

A MANUAL CAMERA and film recorded these star trails. The author took this 3-hour-long exposure of the north circumpolar stars from a dark-sky site near the White Mountains in New Hampshire. She used a Nikon FM2 manual camera with a 24mm lens and ISO 400 slide film. Polaris lies near the center of the bull's eye pattern in this image.

10 TIPS FOR SKY-IMAGING SUCCESS

1 Check your aperture and focus. If your camera has manual controls, open your lens wide or stop it down slightly and use the camera's manual focus to set the lens at infinity (∞). Otherwise, you'll have to use the camera's autofocus and autoexposure modes. To aid with focusing your 35mm single-lens-reflex (SLR) camera, try an optional right-angle magnifier for the viewfinder.

2 Make sure your image's horizon is level. A photographic equipment dealer can sell you a bubble level that fits into the camera's hot shoe. Get one that adjusts for both horizontal and vertical shots.

3 Use a cable release. Depending on your camera model, you should use either a mechanical or an electronic cable release to minimize camera shake when you open and close the shutter. For an SLR camera, lock the viewfinder mirror up if possible. If your camera doesn't accept a cable release, use its self-timer instead to trip the shutter.

4 Shoot in RAW or highest-quality JPEG. To capture the most detail in an image and preserve its color information using a digital camera, always shoot at the camera's full resolution and apply the least amount of image compression.

5 Watch out for electronic noise. If possible, set your digital camera's ISO setting to 400 or lower and keep the exposures short — to tens of seconds, or perhaps a few minutes. Beyond that, electronic noise ("grain") degrades the image noticeably. If your camera has a noise-reduction feature, try it.

6 "Bracket" your exposures. It's a good idea to shoot as many pictures as possible at various exposure settings in the hope that some of them will be good. This is especially true when shooting in twilight. During the hour before sunrise and after sunset, the ambient light changes quickly. Thus, you must constantly check your exposures as you shoot and make any necessary adjustments.

7 Use a fresh battery. Digital cameras are power hogs, especially when using the LCD screen, so use a fully charged battery. Bring along a spare. Batteries lose their charge in cold weather, so keep them warm in an inside pocket when not in use.

8 Exercise caution in the field. Use a red-filtered flashlight to avoid injuring yourself or damaging your setup. The extra illumination allows you not only to operate the camera's dials and buttons but also to check the front lens between shots for dew buildup.

9 Dress warmly. Even in summer, nights can get cold. And it doesn't hurt to bring some snacks and hot beverages.

10 Make sure your location is safe and secure. If possible, have a buddy with you and keep your cell phone handy. Ensure your vehicle is in good running condition. Finally, let someone know where you're going and when you expect to return. — *I. J.*

do the rest. For best results, be sure your site is dark.

During a long exposure, you can fire an external flash to fill in foreground details. Or you can "paint" an object in silhouette with a small flashlight to add some glow or highlight along its edges.

When choosing a suitable foreground, try to frame the Moon and planets over a pond or a lake so you can capture their "glittering paths" (reflections) on the water's surface. The multicolored trails of stars reflected on water are also photogenic.

Unlike film cameras, digital cameras can't take multiple shots on a single frame. To overcome this, you can shoot a series of exposures and use Adobe *Photoshop* or other graphics-editing programs to digitally combine the best frames and create a composite. You can also use *Photoshop* to enhance the image's overall quality by cropping it or adjusting its brightness, contrast, and color balance.

Whether you use a film or digital camera to shoot the sky, one thing's certain: Capturing great sky scenes requires planning, patience, and practice. Armed with the right gear, proper techniques, and a list of upcoming events, you'll shoot beautiful sky scenes in all their grandeur.

Webtalk

Tour the sky with Astronomy.com

Watch exclusive videos with tips on observing and the latest information on astronomy equipment. Customize StarDome to plot stars, planets, and more for your location. Download wallpaper and bring the universe on to your desktop.

June web extras

Subscriber-only web extras bring you additional research, interviews, photographs, and animations that our editors turned up while creating the magazine stories.

"Our galaxy's date with destruction" p. 28
Author T. J. Cox narrates the merger simulation of the Milky Way and the Andromeda Galaxy.

"How we junked up outer space" p. 40
See an animation that shows how space junk increased over time.

"Do cosmic flashes reveal secrets of the infant universe?" p. 34
Watch a gamma-ray burst as it happens in an animation created by Dana Berry.

"Ask Astro" p. 62
Listen to a podcast on how to measure distances to stars.

NASA
Hubble is one satellite skywatchers observe.

"Observing artificial satellites" p. 74
Learn about the 50-year history of observing satellites.

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- **Web extras that complement magazine articles**
- **"The Sky This Month" showcases observable events this month**

It's showtime!

Our exclusive videos share how-to tips, explain science headlines, showcase equipment, and more.

Featured video

HOW TO OBSERVE NEBULAE
Astronomy Editor David J. Eicher gives tips for teasing out faint details in these celestial clouds.

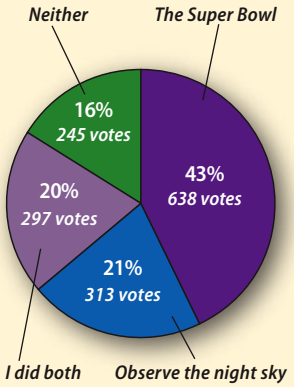
This month's top blogs

Editors put their spin on current events in the staff blog. You can share your opinions on news headlines and popular culture, too.

1. **REALLY-DARK-SKY OBSERVING.** The night sky at the Arizona Sky Village comes straight out of an amateur astronomer's dream. **BY DAVID J. EICHER**
2. **I AM WOMAN, WATCH ME OBSERVE.** Female astronomers and science writers from the 19th-century were pioneers. Maria Mitchell was one ground-breaker who helped lead the way for women astronomers. **BY MICHAEL E. BAKICH**
3. **WINTER STAR PARTY 2008.** With enlightening lectures, helpful workshops, and quality observing, the Winter Star Party 2008 was one to remember. **BY JEREMY McGOVERN**

Online poll results

Did you watch the Super Bowl or observe the night sky?



Total votes: 1,493

Join the fun! You'll find the weekly question on the lower right side of the home page.

M. NEESER/P. BARTHEL/H. HEYER/H. BOFFIN
Spiral galaxy M66 is located in the constellation Leo.

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1.5 MILLION GALAXIES REVEALED
Caltech astronomer Thomas Jarrett explains the science behind the beauty of the Two Micron All Sky Survey.

SCOTT ROBERTS
Amateur-astronomy advocate Scott Roberts forecasts the future of the hobby.

TOURING LEO
Listen as Senior Editor Michael E. Bakich takes you through the constellation Leo the Lion.

BY GLENN CHAPLE

Tour the sky with a small scope

When I'm not eating, drinking, and sleeping astronomy, I turn to angling. I particularly enjoy ultralight fishing, attempting to subdue large fish on light tackle. Perhaps that's why I take pleasure in "ultralight astronomy" — the quest to capture cosmic trophies with small-aperture telescopes. Whether the quarry is in water or the sky, I get plenty of satisfaction "landing the big one" with modest equipment.

Last month, I praised 60mm refractors, noting that even a department store model can evolve into a capable performer with a surprisingly large eye on the universe. Long considered a beginner-only toy, it's actually a worthy backup telescope for the seasoned skygazer. An evening session with a 60mm refractor brings me back to my astronomical roots. Nostalgia aside, a small scope is simply fun to use! If you have a 60mm refractor at your disposal, take it outside and try these currently visible targets.

The Moon

No telescopic sight in the night sky packs the visual impact of the **Moon**. The sight of its rugged, cratered surface evokes gasps of awe from first-time observers and veterans alike. Medium magnifications (50x to 60x) reveal a wealth of detail. Jump to 100x to 120x — about the maximum useful power for 60mm — and the view is breathtaking! This month, our best window of opportunity for lunar excursions is between June 6 when the Moon is a crescent low in the west after sunset, and June 16, when it's nearly full.

The planets

After sunset, two planets vie for our attention — **Saturn**, low in the western sky, and **Jupiter** rising in the east.

We'll need just 30x to 50x to glimpse Saturn's rings. A little "star" nearby is Saturn's biggest moon, Titan. Nightly observations for several weeks allow us to track its orbital path around Saturn.

A SMALL SCOPE captured this view, but image processing brought out the Ring Nebula (arrow) and Comet 17P/Holmes (center). JOHN CHUMACK AND WILLIAM TROSTS

Low power also suffices for Jupiter, whose slightly flattened, banded disk, and four Galilean moons are evident. Following the night-to-night dance of these satellites around the giant planet is a small-scope treat.

Double stars

Double stars are a visual delight when viewed with a small refractor. We'll start our double-star odyssey with **Mizar**, a striking snow-white pair situated in the middle of the handle of the Big Dipper. For a touch of color, we'll travel to **Albireo** in Cygnus the Swan. Albireo's amber and sapphire hues are simply dazzling! Mizar and Albireo can both be split with just 25x. Finally, we'll double our pleasure with the famous **Double Double** (Epsilon [ε] Lyrae). Steady seeing and 100x are paramount for a clean split of these tight side-by-side pairs.

Two more deep-sky gems

If double stars aren't enough, we can always take the Messier route. All of the Messier objects plotted on the June all-sky map are within reach of a 60mm refractor. Two easy-to-find examples are the **Ring Nebula** (M57) and the **Hercules Cluster** (M13).

To find M57, carefully search with low power the area midway between Beta (β) and Gamma (γ) Lyrae. Once you spot a little 60" by 85" puffball, zoom to 100x for a better view.

A few years back, I mistakenly wrote that M57's "ringness" could be captured only in scopes of 150mm aperture or more — anything less would show only a solid, hazy oval. Last fall, I finally saw the Ring with an 80mm scope. Although I imagine someone in a dark-sky location could accomplish this feat with a 60mm refractor, most of us will be content to see the "Oval Nebula."

M13, conveniently situated near the Keystone asterism of Hercules, takes us even farther away — about 25,000 light-years. This cluster, a colossal spherical gathering of hundreds of thousands of suns, appears as a hazy ball about one-half the Moon's apparent diameter. A dark-sky observer working with 100x might see a faint sprinkling from some of the brightest cluster members.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: Looking at asterisms. Clear skies!

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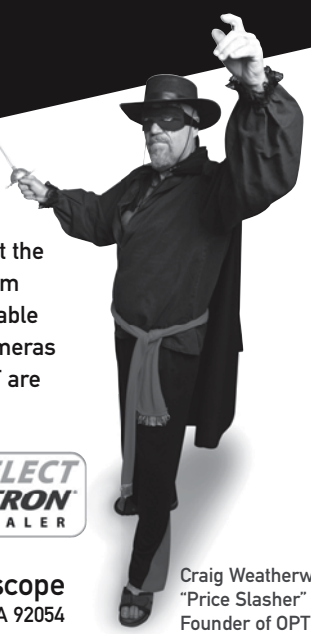

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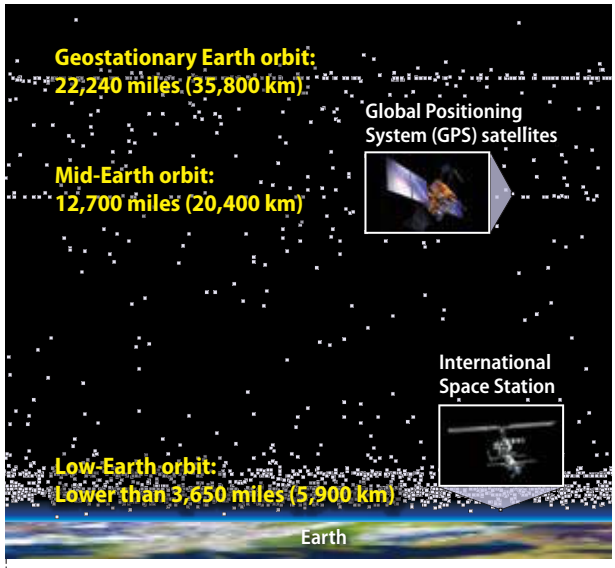
BY PHIL HARRINGTON

How to observe artificial satellites

A few summers ago, I attended the Astroblast astronomy convention in Franklin, Pennsylvania, sponsored each year by the Oil Region Astronomical Society. One of the speakers that afternoon, Eric Fischer from Allison Park, Pennsylvania, gave a fascinating presentation titled "If Sherlock Holmes Observed Artificial Satellites." Earth-orbiting satellites pass overhead every night, but few of us pay them much mind apart from some idle curiosity. Fischer's presentation showed how you can deduce what kind of satellite you're seeing by the power of observation.

The best time to view satellites is during and immediately after sunset or just before dawn. Either way, the observer is in darkness, but satellites, orbiting far above, are still in sunlight. The Sun's high angle in the summer sky makes this the best season for viewing artificial satellites. Depending on its altitude, a satellite may still be illuminated by sunlight several hours after sunset.



ASTRONOMY: ROEN KELLY

THE SATELLITE'S ALTITUDE affects the observer's ability to view it. Some satellites in a geostationary Earth orbit are observable through a telescope, but not binoculars.

Many resources are available to help identify a sighting, and even predict when a specific target will pass through the local sky. However, Fischer's talk emphasized that it's much more fun to identify satellites based on a mystery object's appearance. So, let's put on our detective caps and do a little investigating for ourselves.

First, you need to know where to look. Although satellites can appear in nearly any direction, in general, you'll do best to face away from the Sun. During the evening, focus on the eastern half of the sky, and the western half in the early morning. Concentrate 30° or more above the horizon to avoid haze and clouds. A lounge chair tilted back is perfect for sweeping the sky.

You're probably going to see impostors along the way. These may be anything from bright stars like Vega to high-altitude aircraft. If you're seeing a satellite or some other phenomenon, remember that satellites move but never have landing lights!

Once you spot a real satellite, take note of its direction of travel, speed, and brightness. At least a dozen or more genuine candidates could be visible every clear night this time of year.

Astronomical and scientific satellites, such as the Hubble Space Telescope, move west to east. A satellite following a path more southwest-to-northeast or northwest-to-southeast may be a manned mission, such as the International Space Station. A north-to-south or south-to-north path probably means the satellite is related to meteorological or Earth environmental studies. Finally, if a satellite follows a retrograde (southeast-to-northwest) path, it may be a spy satellite. Shhh!

The speed of the passage will give you some idea of its orbital altitude. The higher above Earth it is, the longer a satellite will take to traverse the sky. Tied into this is an object's magnitude. If a satellite appears very bright, but moves very slowly, then it is most likely large and in a high orbit. An equally bright satellite that moves quickly, however, is probably comparatively small.

Several web sites provide more satellite information. The best resource for predicting where a particular satellite will be visible from a given location is www.heavens-above.com. For more observing tips, visit www.satobs.org.

Comments, suggestions, and observations? E-mail me at phil@philharrington.net. Next month: Antares and a garden trowel. Until then, remember that two eyes are better than one.

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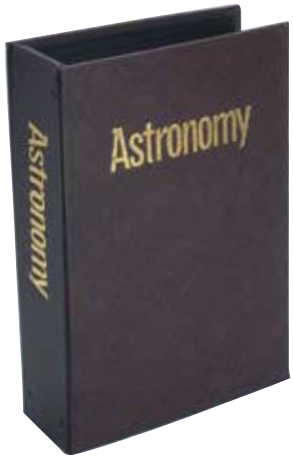

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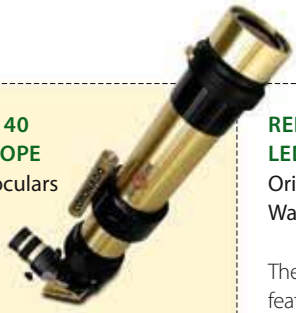

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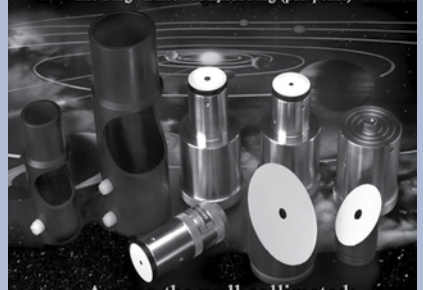

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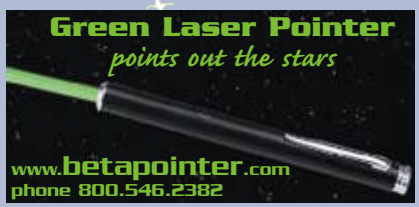

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THE MOON IN EARTH'S SHADOW

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On February 20, 2008, the Moon treated some European and all North and South American observers to another lunar eclipse. The Moon appeared against the background stars of Leo the Lion with that constellation's brightest star, Regulus, a scant 4° above the eclipsed orb. Saturn sat even closer to the Moon, about 3° to its lower left. Most observers described the Moon's color at mid-totality as "copper," although a few saw it as "blood red." This total lunar eclipse was the last until December 20, 2010.

ECLIPSE MONTAGE (4-inch Celestron refractor at f/10, Canon Digital Rebel XTi, ISO 200, exposures of 2, 2, 8, 8, 8, 2, and 2 seconds, respectively, taken February 20, 2008) /// **PHIL HARRINGTON, MILLER PLACE, NEW YORK**

OPEN CLUSTER NGC 6834 lies in the rich star fields of Cygnus. Planetary nebula NGC 6842 in Vulpecula lies 38' to its east. (4-inch Tele Vue NP101 apochromatic refractor, SBIG ST2000XM CCD camera, LRGB image with exposures of 150, 120, 60, and 60 minutes, respectively) /// **BERNHARD HUBL, SCHLIERBACH, AUSTRIA**

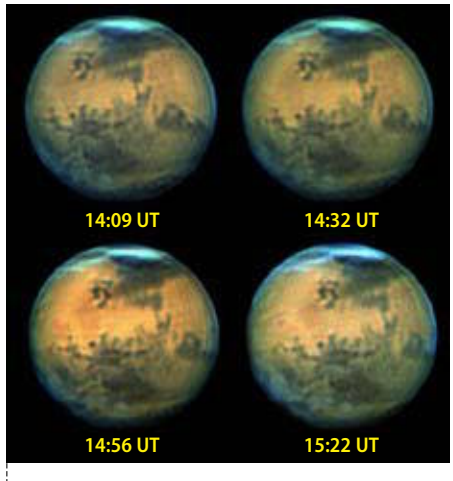
SPIRAL GALAXY M106 in Ursa Major shows reddish hydrogen clouds along its spiral arms. One of the brightest Messier galaxies, M106 shines at magnitude 8.4. (9.25-inch Celestron C925 Schmidt-Cassegrain telescope, SBIG STL-10XME CCD camera, LHαRGB image with exposures of 600, 300, 100, 70, and 150 minutes, respectively) /// **FILIPPO CIFERRI, ROME**

Send your images to: *Astronomy* Reader gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of image and complete photo data: telescope, camera, and exposure information. To submit images electronically, visit www.contribute.kalmbach.com.

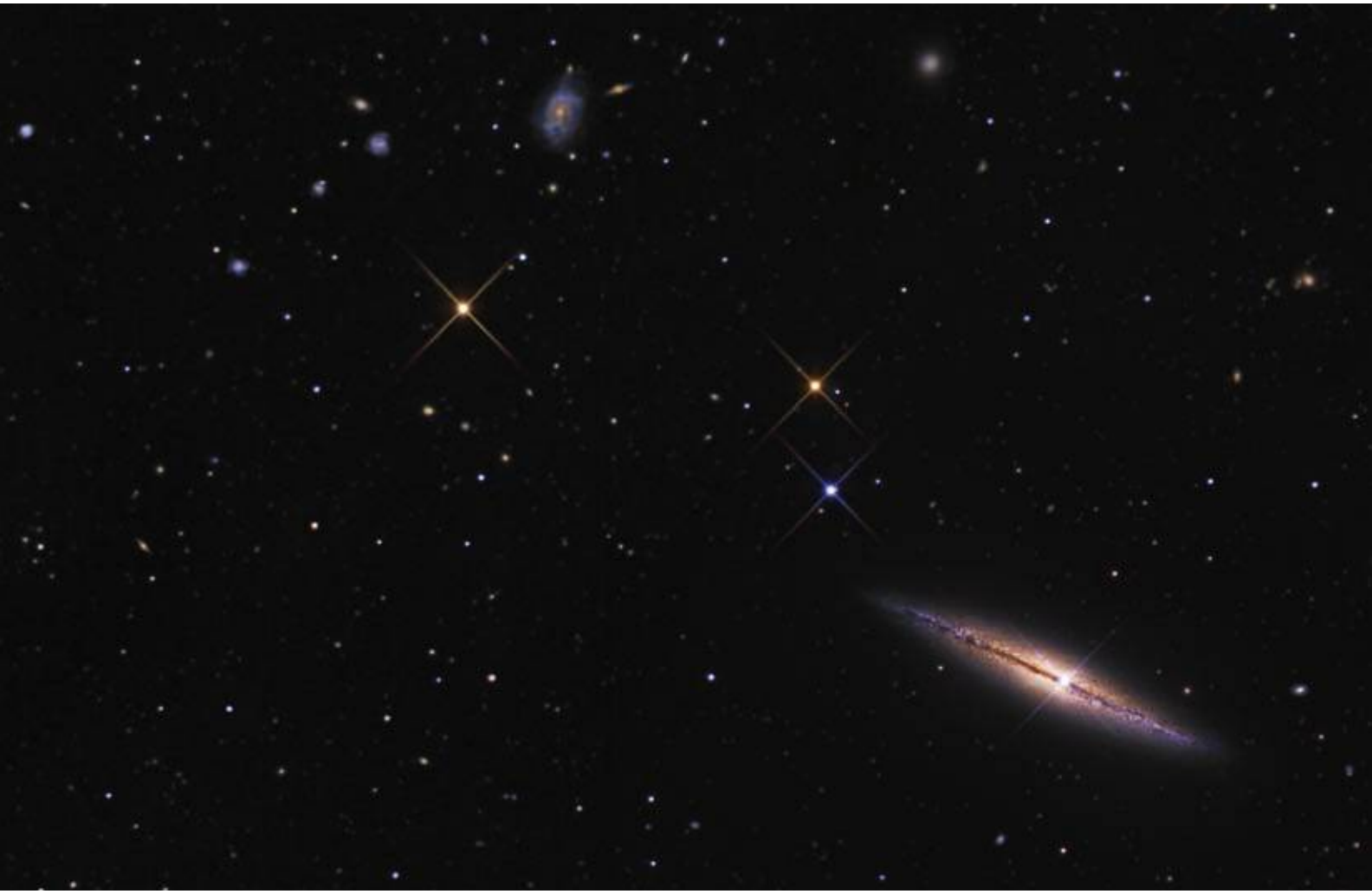
EMISSION NEBULA IC 2944 is a star-forming region in the southern constellation Centaurus. This object contains dense, opaque dust clouds called globules, which, eventually, will form stars. (Takahashi BRC-250 Ritchey-Chrétien telescope at f/4.9, SBIG STL-11000XMC CCD camera, 15-minute images totaling 22 hours of exposure time) /// **RYAN M. HANNAHOE, MAYHILL, NEW MEXICO**

THIS WIDE FIELD image shows the totally eclipsed Moon shining faintly in front of Leo the Lion's stars. Regulus (Alpha [α] Leonis) is to the Moon's upper left and Saturn sits to the Moon's lower left. (Canon EOS 40D digital SLR, 17mm lens at f/4 ISO 1000, 60-second exposure taken February 20, 2008, at 8:51:30 P.M. MST) /// **DEAN SALMAN, TUCSON, ARIZONA**

GLOBULAR CLUSTER M28 in Sagittarius shines at magnitude 6.9 and measures 14' across. It lies approximately 18,000 light-years away. (14-inch Celestron CGE 1400 Schmidt-Cassegrain telescope, Starlight Xpress MX916 CCD camera, LRGB image with exposures of 30, 20, 15, and 25 minutes, respectively) /// **AL KELLY, FRIENDSWOOD, TEXAS**

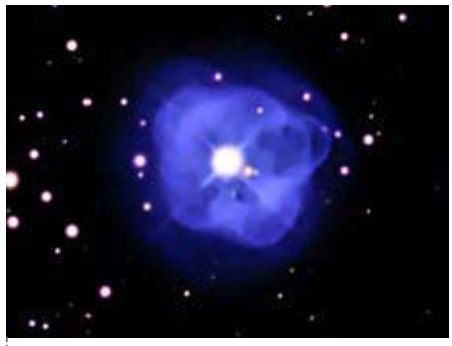


MARS' DAY is only 37.4 minutes longer than ours. This sequence, which features Mars' Chryse region captures about 5 percent of a full rotation. (11-inch Celestron Schmidt-Cassegrain telescope, Imaging Source DMK21BF04 CCD camera, Astro-Physics 3x Barcon Barlow lens, taken December 29, 2007) /// **CHRISTOPHER GO, CEBU, PHILIPPINES**



SPIRAL GALAXY NGC 4013 in Ursa Major represents an "edge-on" galaxy. The dark regions are areas of future star formation. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 630, 90, 54, and 108 minutes, respectively) /// **R. JAY GABANY, SAN JOSE, CALIFORNIA**

OPEN CLUSTER M47 shines at magnitude 5.2 and measures 30' across. Italian astronomer Giovanni Batista Hodierna discovered it more than a century before Messier. (6.4-inch Astro-Physics StarFire EDF apochromatic refractor at f/7.5, SBIG ST-2000XM CCD camera, LRGB image with 30-minute exposures through all filters) /// **ANTHONY AYIOMAMITIS, ATHENS, GREECE**



PLANETARY NEBULA NGC 1514 in Taurus has a dim, smooth outer shell and a brighter inner shell. Through large amateur telescopes, parts of the inner shell appear denser than others. (16-inch RC Optical Systems Ritchey-Chrétien telescope, SBIG STL-6303 CCD camera, HαRGB image with exposures of 7, 2, 2, and 2 hours, respectively) /// **KEITH B. QUATTROCCHI, CLOVIS, CALIFORNIA**

FOR THIS SHOT of February's total lunar eclipse, Tunç Tezel drove 590 miles (950 kilometers). He noted totality during this eclipse appeared much redder than the March 3, 2007, total lunar eclipse. (8-inch Meade LX10 Schmidt-Cassegrain telescope at f/10, Canon EOS 5D digital SLR, ISO 400, 6-second exposure, taken February 21, 2008, at 3h29m UT from Kas, Turkey) /// **TUNÇ TEZEL, BURSA, TURKEY**

HIND'S CRIMSON STAR (R Leporis) represents a carbon star — a variable star that builds up carbon compounds within its outer atmosphere. Such stars are intensely red. (14-inch Celestron CGE 1400 at f/5.5, Starlight Xpress MX916 CCD camera, RGB image with exposures of 300, 180, and 210 seconds, respectively) /// **AL KELLY, FRIENDSWOOD, TEXAS**

THE SNOWMAN NEBULA is the name astroimager Keith Schlottman gave to emission nebula Sharpless 2–302. This faint object lies nearly 6,000 light-years away in Puppis. (4-inch William Optics Zenithstar 105 at f/5.6, SBIG ST-10XME CCD camera, HαRGB image with exposures of 380, 50, 30, and 40 minutes, respectively) /// **KEITH SCHLOTTMAN, TUCSON, ARIZONA**

THE ECLIPSED MOON, Saturn (above the Moon), and Leo's brightest star, Regulus, appear above the Temple of Poseidon in Greece. Ayiomamitis used his car's headlights to illuminate the temple during the exposure. (Canon EOS 300D digital SLR, Canon EOS EF 28-105 lens at 78mm and f/4, 8-second exposure taken at Sounion, Greece, February 21, 2008, at 3h40m32s UT) /// **ANTHONY AYIOMAMITIS, ATHENS, GREECE**

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